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This report presents an analysis of alternative motor vehicle basic inspection and maintenance programs in terms of related costs and benefits for the State of South Carolina with specific information covering Lexington, Richland, Charleston, and Berkley Counties. The study methodology used is described and includes collecting data, determining criteria for selecting alternative program configuration, screening program option and evaluating alternative configuration selected through the screening process. Program alternatives were evaluated in terms of emission reduction attainable, geographic coverage, effective motor vehicle population, consumer protection, quality assurance, costs and financial feasiblity.

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MOTOR VEHICLE EMISSIONS
INSPECTION/MAINTENANCE
PROGRAM FOR
SOUTH CAROLINA

BY:

JOHN GUNDERSON
EMIL J. VODONICK
GARY PAN
DAVID D. CLARK
JIM GATACRE

SYSTEMS CONTROL, INC.
ENVIRONMENTAL ENGINEERING DIVISION
421 EAST CERRITOS AVENUE
ANAHEIM, CALIFORNIA 92805

IN ASSOCIATION WITH:

PACIFIC ENVIRONMENTAL SERVICES, INC.
SANTA MONICA, CALIFORNIA

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PROJECT OFFICER
WALLY JONES
U.S. ENVIRONMENTAL PROTECTION AGENCY REGION IV
ATLANTA, GEORGIA

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ABSTRACT

This document was prepared to assist the South Carolina Department of Highways and Public Transportation (SCDHPT) in the evaluation and development of a Motor Vehicle Inspection/Maintenance (I/M) program for the State. I/M was designated by the Clean Air Act Amendment of 1977 as a method by which ambient air quality standards may be achieved by 1982. If standards cannot be attained by 1982, an extension of compliance to 1987 may be obtained, in which case I/M implementation will be mandatory.

This report presents an analysis of costs and benefits associated with a basic I/M program that could be implemented in South Carolina. Study efforts were limited to nonattainment geographic areas over 200,000 population, namely Berkeley, Charleston, Lexington, and Richland Counties. For comparative purposes, a cost analysis for a decentralized statewide program was also performed. Three alternative options for administration of an I/M program were studied; state operation, contractor operation, and private-garage operation.

Based upon cost information, the preferred option selected by the State was the private garage integrated with an existing safety program. Due to increased equipment and operating costs, only the idle-mode option was investigated.

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Section 1

EXECUTIVE SUMMARY

A. WHY AN INSPECTION/MAINTENANCE (I/M) PROGRAM

Recent ambient air quality data for the State of South Carolina indicates violations of the National Ambient Air Quality Standards (NAAQS) for carbon monoxide (CO) and photochemical oxidants. Because of these violations, the Environmental Protection Agency (EPA) and the State of South Carolina Department of Health and Environmental Control, designated the urban areas of Columbia and Charleston as non-attainment. These national standards have been established in order to protect the health and welfare of the population. Both CO and O_x are gases which, in sufficient concentrations in the atmosphere are potentially harmful to the public health.

A major source of CO and photochemical oxidants in South Carolina are motor vehicles. Carbon monoxide is a product of incomplete combustion of an internal combustion engine. Photochemical oxidants are indirect products, formed through a complex series of atmospheric reactions of two other direct products of combustion, reactive hydrocarbons (HC), and oxides of nitrogen (NO_x) in the presence of sunlight. An I/M program is a cost-effective strategy to reduce CO and HC emissions from motor vehicles. By significantly reducing the emission of HC and CO from in-use vehicles in South Carolina, an I/M program will enhance the attainment of NAAQS.

The Clean Air Act Amendments (CAAA) of 1977 have specific provisions that require the establishment of I/M programs. According to the CAAA the state was to submit revisions to its State Implementation Plan (SIP) by January 1979, which specifies methods to achieve the NAAQS. These methods include control of stationary sources of air pollution and various transportation control measures whose objective is to reduce vehicle miles traveled (VMT) and hence, reduce pollution from mobile sources. If, in these revisions, the state cannot demonstrate attainment of the NAAQS by 1982 using all reasonably available pollution control measures, then an extension to 1987 can be requested. If an extension is granted a mandatory I/M program will be required by the CAAA. Based upon the SIP provisions, the NAAQS can not be attained in Berkeley, Charleston, Lexington and Richland Counties of South Carolina by December 1982. The CAAA of 1977 provides that if a nonattainment area does not implement a mandatory program, then Federal funds will be withheld for 1) highways, except safety, mass transit, or transportation improvement programs related to air quality improvements; 2) sewage treatment grants; and 3) air quality planning grants.

1. Inspection/Maintenance Programs

Inspection/Maintenance is a two-phase emission control program applied periodically to all in-use vehicles. The inspection (Phase 1) of an I/M program serves as a screening procedure to identify vehicles having emissions which exceed established standards. The maintenance (Phase 2) of an I/M program involves the repair of those vehicles that exceed the established standards. Vehicles that have failed the inspection phase are required to obtain corrective repair in order to pass inspection retest.

The Federal Motor Vehicle Control Program (FMVCP) was established to ensure that new cars, off the assembly line, are designed to meet increasingly stringent emission standards. Federal testing of in-use vehicles throughout the United States has demonstrated that motor vehicles are not meeting the emission standards for which the vehicles were designed. The reasons they exceed the standards include: improper or inadequate maintenance, tampering, defective emission control devices, and fuel switching. Regardless of the cause, it has become clear that some in-use vehicle emission inspection programs are necessary to ensure that the emission controls on vehicles continue to operate as they were intended over their useful life.

a. Program Organizational Approach

A variety of approaches have been used to run I/M programs, but the major types are generally in three organizational categories:

1. State - Centralized test facilities operated by state, city, or local government.
2. Contractor - Centralized test facilities operated by a private corporation under contract to the State.
3. Private Garage - Decentralized test facilities operated by private automobile service garages, certified or licensed by the State.

Each type of administrative program is compared qualitatively by identifying responsibilities, functions, and roles in the emission test process as shown in Table 1. In each program, the State plays an integral part by auditing records, maintaining quality control checks, certifying contractor or private stations, and assuring consumer protection.

b. Background Information on Present I/M programs

Inspection/maintenance programs currently operating throughout the country are presented in Table 2. All available information is summarized under the following categories: program type, size of subject vehicle population, emission test, station requirements, cost (i.e., capital and operational), and consumer fee charges.

Govenment I/M programs can be further subdivided into either state or municipally-owned/operated programs. New Jersey operates a state program that annually idle-tests 3.9 million light-duty vehicles (LDVs) at 38 stations (62 lane total capacity). This requires $2.5 and $1.3 million dollars in capital and operating costs, respectively. Oregon idle-tests 0.55 million vehicles at 7 inspection stations on a biennial basis in the City of Portland. Capital costs are $0.38 million dollars for leased facilities, and operating costs are $2.22 million dollars. Consumer fee is estimated at $5.00 per vehicle.

Table 1. QUALITATIVE COMPARISON OF ADMINISTRATIVE PROGRAM OPTIONS

COST CATEGORIES AND CONSIDERATIONS	STATE-OPERATED	CONTRACTOR-OPERATED	PRIVATE GARAGE-OPERATED
Instrumentation and Technology	Design, requirements analysis, and specification development is required.	Will have expertise in these areas.	Will have some basic expertise, but will need to be expanded.
Site Acquisition	Initial capital cost required.	Low capital cost to state, deferred to operational charge.	Capital invested already.
Facility Construction and Acceptance	Capital investment required, local government approval to meet zoning laws.	Contractor agency will require building inspection approval by the State and local government.	Facilities available.
Equipment Acquisition and Installation	Volume discount.	Moderate cost volume discount.	Each participating garage will have to purchase equipment that it does not already have.
Maintenance and Support, Inspection-Oriented Equipment	Preventive maintenance done by facility personnel; major corrective maintenance done either by a single technical department or contracted outside service; moderate cost to State.	Minor corrective maintenance done by facility personnel; major corrective maintenance done by contracted service; no cost to State.	Preventive and minor corrective maintenance done by facility personnel; major corrective maintenance probably done by contracted service; no cost to State.
Quality Control and Support Activities	Periodic confidence testing and calibration functions; minor repairs of supporting equipments done by facility personnel; major repairs done by single department or contracted; moderate cost to State.	Periodic confidence testing and calibration of minimum number of stations by state. Data processing by state.	Performed by State agency. Numerous stations to be checked. Data processing input from card decks.

Table 1. QUALITATIVE COMPARISON OF ADMINISTRATIVE PROGRAM OPTIONS (Continued)

COST CATEGORIES AND CONSIDERATIONS	STATE-OPERATED	CONTRACTOR-OPERATED	PRIVATE GARAGE-OPERATED
Program Management and Functions	Maintain records, schedule vehicles, collect fees, review emission results, update standards and documentation, determine future requirements, evaluate newer equipments, determine budgetary requirements, and other program management functions; may involve many separate State agencies, new and/or existing; moderate cost to State.	Similar management functions to State operated program, but with State agency that oversees contractor administration; moderate cost to State.	Requires State to audit all records on regular basis; high cost to State.
Program Management and Administration Surveillance Program	Periodic certification of existing facilities; qualification/certification of new facilities; moderate cost to State.	Periodic certification of contractor facilities by State inspection team; moderate cost to State.	Private-operated facilities certified by State personnel; high cost to State.
Initial Personnel Training and Indoctrination	Single department responsibility; uniform training policy, course content; minimum quantity of trained instructors, equipment, buildings; moderate cost to State.	Require single department responsible for training, etc.; minimal cost to the State.	Possibly many diverse training policies, course contents, equipment, facilities, instructors; requires guidance from State agency on requirements; minimal cost to State.
State Qualification and Certification	Single departmental responsibility; uniform qualification and certification policies; minimum quantity of technical and administrative personnel; moderate cost to State.	State responsibility to supervise initial operation of program; moderate cost to State.	Mandatory that State qualify and certify stations; high cost to State.

Table 1. QUALITATIVE COMPARISON OF ADMINISTRATIVE PROGRAM OPTIONS (Continued)

COST CATEGORIES AND CONSIDERATIONS	STATE-OPERATED	CONTRACTOR-OPERATED	PRIVATE GARAGE-OPERATED
Vehicle Scheduling	Single departmental responsibility.	Mandatory that State be responsible.	Mandatory that State be responsible.
Facility Inspection Personnel Salaries, wages, etc.	Technical rating dependent on test regime; cost proportional to technical requirements; salaries and benefits must be competitive to attract higher-rated personnel; high cost to State.	Technical rating dependent on test regime requirements.	Technical rating depends on test regime; cost proportional to technical rating.
Quality Assurance	Responsible for complete audit of all records; complete data analysis; adjusting confidence limits; moderate cost to State.	Calibration records frequently audited by State personnel; State responsible for complete data analyses; moderate cost to State.	Difficult to implement because of instrument differences, diversified personnel; high cost to State.

Table 2. EXISTING I/M PROGRAM SUMMARY

PROGRAM TYPE	STATE	ADMINISTRATIVE AGENCY	VEHICLE POP (Millions)	TEST MODE AND STRINGENCY[a]		STATION STATUS			COST (Millions $ Yr)		INSPECTION FEE
				L.D.V.	H.D.V.	#Lanes	#Sta.	Mobile	Capital[b]	Operating[b]	
I. GOVERNMENT											
A. State	New Jersey	DMV - EPA	3.9 LDVs	Idle 23%	NA	62	38	1	$2.50 (1972) +	$1.33	$3.50 including safety
	Oregon[c] Portland	Dept. of Environ. Qual.	0.55 LDVs (biennial)	Idle 40%	NA	14	7	1	$0.38 Leased facil. (1975)	$2.22	$5
B. Municipal	Ohio, Cincinnati	Cincinnati APCD[d]	0.2 LDVs	Idle 30%	NA	4	1	None	$0.013 safety facil.	$0.13 for	$3.75 including safety
	Illinois, Chicago	Chicago Dept. Env. Control	1.1 LDVs	Idle 30-35%	NA	10	5	6	$2.0 (1973)	$1.45 (1977)	Free[e,f]
II. CONTRACTOR	Arizona,[g] Maricopa and Pima counties	Ariz. Dept./ Health Ser.	1.1 cars, trucks, and motorcycles	Idle[h] 30%	EPA City	36	12	1	$10.5	$4.0	$5
III. PRIVATE GARAGE	Nevada (Clark Co. only)	Dept. Motor Vehicles and Dept. Human Resources	0.20 LDVs	Idle	NA	218 Licensed Private Stations			$0.17 (1974)	$0.43 approx. (1974)	$10.00-$33.00 (including adjustments)
	Rhode Island	Dept. of Transportation	0.5 LDVs	Idle 30%	NA	923 Private Garages + 1 State-Operated challenge lane			$1.00 (1977)	Part of Capital cost 1st year	$4

[a] Percent of vehicle failing to meet established standards.

[b] Cost data defined per particular year. To upgrade costs to present year multiply by appropriate inflation factor.

[c] State of Oregon, Oregon Environmental Quality Commission - "Report to the Oregon Legislature on the Motor Vehicle Emission Testing Program," January 14, 1977.

[d] Air Pollution Control Department.

[e] Included as part of the registration fee.

[f] Chicago's program costs are covered by a city sticker fee.
Definitions: DMV - Department of Motor Vehicles.
LDV - Light-Duty Vehicle (GVW <8501 lb.).
HDV - Heavy-Duty Vehicle (GVW >8500 lb.).

[g] State of Arizona, Bureau of Vehicular Emissions Inspections - "Tune-up for Less Emission - It's Working Arizona Vehicular Emissions Inspection Program Operations", 1977.

[h] Loaded test with only idle fail/pass standards.

Municipally-operated programs are found in Ohio (Cincinnati), and Illinois (Chicago). These programs annually inspect 0.2 to 1.1 million vehicles. Ohio has only one test facility, but intends to expand the program later. Illinois currently operates five 2-lane capacity test facilities. In addition, Illinois operates six mobile test facilities. Ohio capital cost is $13,000 and operating cost is $0.13 million. Illinois expenditures are $2.0 million for capital costs and $1.45 million annual operating expenses.

The only contractor-owned/operated program is located in Arizona (Maricopa and Pima Counties). The 12 test facilities annually process an estimated 1.1 million cars, trucks, and motorcycles using 30 percent stringency factor with idle test requirements. Capital cost expenditures are estimated at $10.5 million with annual operating costs approaching $4.0 million.

At present, Nevada and Rhode Island are the only states that have private garage-operated I/M programs. Rhode Island has an extensive program, testing 0.5 million vehicles at 923 certified private garages. The Nevada program is comparatively smaller, licensing only 218 garages to test 200,000 vehicles. As expected, the capital cost expenditure for Rhode Island is quite large compared to Nevada. Unexpectedly, the cost to the motorist is quite high for Nevada ($10.00 to $33.00) compared to Rhode Island ($4.00). However, the Nevada program does have vehicle adjustment included in the test requirements.

For each I/M program type, typical problems encountered during implementation, and their subsequent solutions, are shown in Table 3. Additional information includes representative achievements for each state I/M program.

2. I/M Implementation Schedule

In producing an I/M SIP revision, the state must provide for:

1. An analysis of the benefits and costs of the program,
2. A public information effort,
3. A legislative proposal, and
4. A schedule for I/M implementation.

Table 3. TYPICAL I/M PROBLEMS, SOLUTIONS AND ACHIEVEMENTS

PROGRAM TYPE	STATE & RESPONSIBLE AGENCY	PROBLEMS	SOLUTIONS	ACHIEVEMENTS
I. GOVERNMENT-OPERATED				
A. State-Operated	California	.(Pilot Program) Minimal Problems		.Public Reaction Excellent .Unique Combination of Exhaust Analysis, Engine Monitoring, and Computer Technology .Diagnostic Testing
	New Jersey	.2-Year Exemption for New Cars .Lack Operating Capital Capacity Improvements Cannot be Made .DMV Resistant to Increased Refailure Rate Expected in Phase III standards (23%) .Refailure Rate is 25%	.Legislation Pending .Funding Has Increased $330,000 .No Position Change .Refailure Rate Now 11%	.Nation's Longest On-Going I/M Program .4,700 Garages Now Utilizing Exhaust Analyzers .Private Garage Reinspection Program
	Oregon Portland	.Biennial Inspection Lowers Program Effectiveness, Created Cash Flow and Personnel Problems .Tampering	.Inspection Period Will be Shortened .Trying to Implement An Annual Inspection Cycle, Requires Legislation Action	.Estimates Reduction of HC is 14% and CO 7% .Private Garage Acceptance is Increasing
B. Municipal-Operated	Ohio Cincinnati	.Low Throughput .Inadequate Enforcement .No Phase-In Period and No P.R. Program .Mechanics Inadequately Trained	.Improved Enforcement Led to Increased Throughput .P.R. Program Needed .Mechanic Training Program	.Demonstrated Short Lead Time in Adding I/M Program to Safety Program
	Illinois Chicago	.Less Than 20% of Registered Vehicles Have Been Inspected	.Increased Enforcement Policies .Favor Mandatory Inspection with Three Conditions: 1. Fed. Govt. and Auto Manufacturer's Concurrence On Warrantee Program 2. Auto Manufacturer's Compliance With Existing Statutory Emission Standards 3. I/M Implementation Over Regional Area	.Communication Channels Established with Auto Manufacturers Regarding High Emission Levels of Late Model Vehicles .Nation's First Fully Automated Inspection Program

Table 3. TYPICAL I/M PROBLEMS, SOLUTIONS AND ACHIEVEMENTS (Continued)

PROGRAM TYPE	STATE & RESPONSIBLE AGENCY	PROBLEMS	SOLUTIONS	ACHIEVEMENTS
II. CONTRACTOR-OPERATED	Arizona Maricopa and Pima Counties	.Initial Adverse Public Reaction .Queuing Problems .Tampering .Inadequate Inspector Training	.Expected to Disappear With Increased Efficiency and Better Public Awareness .Needs Contractor Monitoring	.Nation's First Contractor-Operated Program
III. PRIVATE GARAGE-OPERATED	Nevada Clark County	.Minimal		.DMV Control of Licensing of Stations and Inspectors .Minimal Cost
	Rhode Island	.Inadequate Training of Garage Mechanics .Some Garages Violated Regulations	.On-Going Mechanic Training Program .Constant Monitoring Needed	.Program Initiated by Governor and Rhode Island DOT With Backing From Executive and Legislative Branches .State-Run Inspection Facility Used as Reference Station

Before January 1, 1979, an SIP revision was prepared by DHEC and submitted to the EPA. As a part of the SIP revision submittal itself, a commitment was made by the Governor to implement the I/M program in accordance with the schedule submitted. This schedule is in accordance with Reference 1. Quoting from Reference 1:

"C. Authority To Implement I/M

Normally, adequate legal authority to implement a SIP revision must exist for a revision to be approved. Where a legislature has had adequate opportunity to adopt enabling legislation before January 1, 1979, the Regional Administrator should require certification that adequate legal authority exists for I/M implementation by January 1, 1979. However, for many states there will be insufficient opportunity to obtain adequate legal authority before their legislatures meet in early 1979. Therefore, a certification of legal authority for the implementation in these states must be made no later than June 30, 1979. An extension to July 1, 1980 is possible, but only when the state can demonstrate that a) there was insufficient opportunity to conduct necessary technical analyses and/or b) the legislature has had no opportunity to consider any necessary enabling legislation for inspection/maintenance between enactment of the 1977 Amendments to the Act and June 30, 1979. Certification of adequate legal authority, or other evidence that legal authority has been adopted, must be submitted to the EPA Regional Offices to be included in the SIP revision already submitted. Failure to submit evidence of legal authority by the appropriate deadline will constitute a failure to submit an essential element of the SIP...."

"D. I/M Implementation Deadlines

Implementation of I/M 'as expeditiously as practicable' shall be defined as implementation of mandatory repair for failed vehicles no later than 2-1/2 years after passage of needed legislation or certification of adequate legal authority for new centralized systems (State or Contractor-operated), and 1-1/2 years after legislation or certification for decentralized systems which are adding emission inspections to safety inspections. For the normal legislation deadline of June 30, 1979, new centralized programs must start by December 31, 1981, and all others must start by December 31, 1982, while all other programs must start by December 31, 1981. Where I/M can be implemented more expeditiously, it must be. Each state implementation schedule must be looked at individually to determine if it is as expeditious as practicable...."

B. BACKGROUND OF THIS STUDY

In order to comply with requirements of the CAAA of 1977, Systems Control, Inc. (SCI), was contracted to study alternative I/M options.

The initial effort was the development of background data regarding the technical and administrative aspects of I/M programs. A summary report which described I/M program elements and other states' experience in I/M and various technical memoranda, was produced to assist in the selection of a preferred option.

The purpose of this report is to analyze the preferred option in terms of cost and benefits such that the Department of Highways and Public Transportation (DHPT) may consider it as a viable option in their SIP to meet NAAQS.

The Preferred Option - As indicated earlier, the DHPT selected the decentralized preferred option of an idle test conducted by private garages measuring HC and CO combined with the existing safety inspection program. The two alternative program scenarios studied are shown in Table 4.

Table 4. PREFERRED OPTION PROGRAM CONSIDERATIONS

PROGRAM CONSIDERATION	SCENARIO 1	SCENARIO 2
Benefits	yes	yes[a]
Costs	yes	yes
Geographic Coverage (see Figure 1)	4-County	Statewide
Inspection Enforcement	Annual Vehicle Registration	Annual Vehicle Registration or Window Sticker

[a] Emission data extrapolated from 4-County data.

In addition to the program considerations listed in Table 4, there are a number of support services that are important to I/M effectiveness and cost, but do not directly influence option selection. These support services include:

- Quality Assurance
- Mechanic Training

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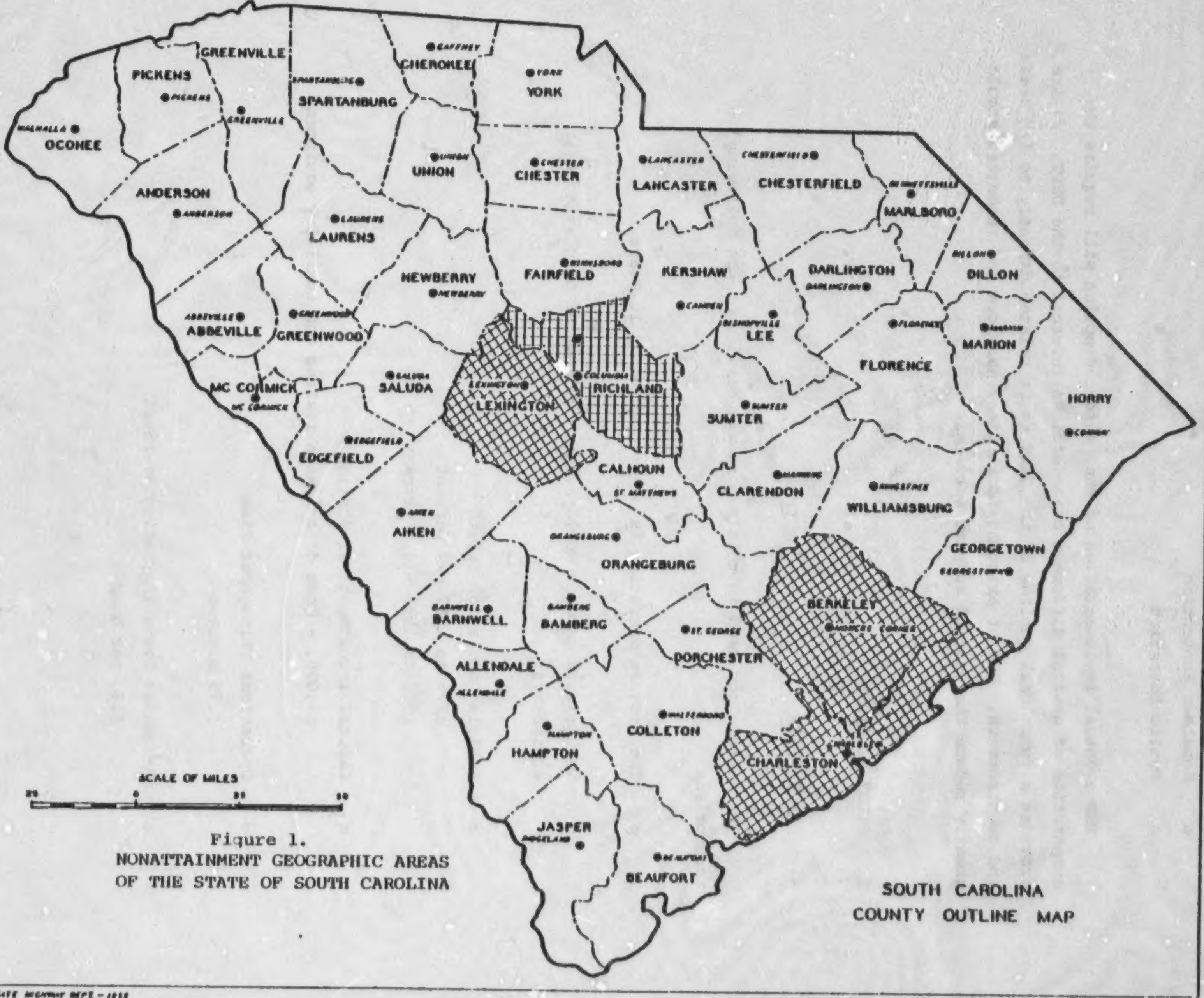
OCONEE
PICKENS
GREENVILLE
SPARTANBURG
CHEROKEE
YORK
ANDERSON
LAURENS
UNION
CHESTER
LANCASTER
CHESTERFIELD
MARLBORO
DILLON
ABBEVILLE
GREENWOOD
NEWBERRY
FAIRFIELD
KERSHAW
DARLINGTON
LEE
FLORENCE
MARION
HORRY
MC CORMICK
SALUDA
LEXINGTON
RICHLAND
SUMTER
EDGEFIELD
CALHOUN
CLARENDON
WILLIAMSBURG
AIKEN
ORANGEBURG
GEORGETOWN
BERKELEY
BARNWELL
BAMBERG
DORCHESTER
ALLENDALE
HAMPTON
COLLETON
CHARLESTON
JASPER
BEAUFORT
SCALE OF MILES
25
0
25
50
SOUTH CAROLINA
COUNTY OUTLINE MAP
S C STATE HIGHWAY DEPT. - 1958

Figure 1.
NONATTAINMENT GEOGRAPHIC AREAS
OF THE STATE OF SOUTH CAROLINA

- Consumer Protection
- Public Education

The eventual implementation of the preferred option will require the cooperation of several different state offices internal to the DHPT. Figure 2 provides a functional outline of the DHPT as it relates directly to I/M needs and requirements. Use of existing facilities, services and resources should greatly reduce the cost of support services.

C. STUDY FINDINGS

1. Assumptions

The methodology used in this report was based upon the following assumptions:

- The program operation is over a period of 10 years
- The private garages would assume the cost of purchasing test equipments.
- Vehicle Population Growth
  1976 to 1982 - 4 percent
  1982 to 1992 - 3.5 percent
- Capital Investment Per Station
  $3,000. - Cost of emission testing and auxiliary equipment
- Operations Throughput Time
  3.75 minutes
- Mechanics Costs (including overhead)
  $18. per hour

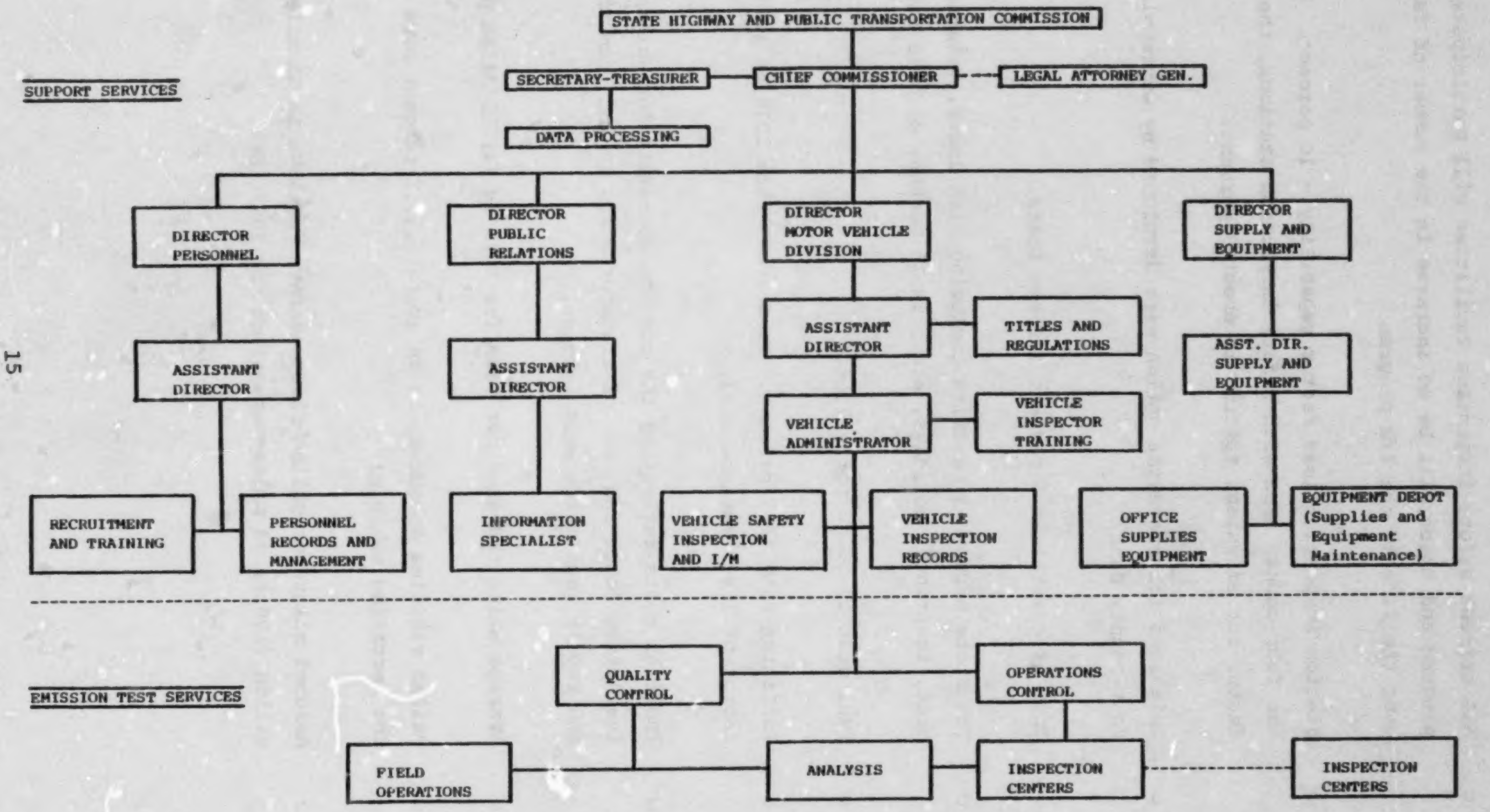
STATE HIGHWAY AND PUBLIC TRANSPORTATION COMMISSION
SUPPORT SERVICES
SECRETARY-TREASURER
CHIEF COMMISSIONER
LEGAL ATTORNEY GEN.
DATA PROCESSING
DIRECTOR PERSONNEL
DIRECTOR PUBLIC RELATIONS
DIRECTOR MOTOR VEHICLE DIVISION
DIRECTOR SUPPLY AND EQUIPMENT
ASSISTANT DIRECTOR
ASSISTANT DIRECTOR
ASSISTANT DIRECTOR
TITLES AND REGULATIONS
ASST. DIR. SUPPLY AND EQUIPMENT
VEHICLE ADMINISTRATOR
VEHICLE INSPECTOR TRAINING
RECRUITMENT AND TRAINING
PERSONNEL RECORDS AND MANAGEMENT
INFORMATION SPECIALIST
VEHICLE SAFETY INSPECTION AND I/M
VEHICLE INSPECTION RECORDS
OFFICE SUPPLIES EQUIPMENT
EQUIPMENT DEPOT (Supplies and Equipment Maintenance)
EMISSION TEST SERVICES
QUALITY CONTROL
OPERATIONS CONTROL
FIELD OPERATIONS
ANALYSIS
INSPECTION CENTERS
INSPECTION CENTERS

Figure 2. SOUTH CAROLINA I/M RESPONSIBILITY CHART

- All current safety inspection facilities will participate in the I/M program and there will be no increase in the number of facilities over the life of the I/M program

- Station inspection load factor capability - 10 percent. NOTE: In the four-county area with safety inspection stations, the load factor for emissions testing is about 3 percent.

- Emissions for statewide option were developed by extrapolating the four-county data.

- Cost of capital is 6 percent for the State.

- The State personnel benefits including sick leave, vacation, retirement, insurance, holidays, etc., is 25 percent of base rate.

- Fuel cost is $0.70 per gallon.

- Inflation rate is 7 percent. To convert from 1978 to 1983, a compound factor of 1.403 must be used.

- Indirect costs reflecting the cost to consumers for waiting time at inspection lanes and cost of transportation to and from the inspection and repair facilities were ignored.

- Average miles traveled per year for LDVs is 11,500 miles per year.

- Failed vehicles consumed, on an average, 3.8 percent more fuel than the certified vehicle.

- Assumed miles-per-gallon fleet average for LDVs is 15 miles-per-gallon (1982), 24 miles-per-gallon for 1987 LDVs.

2. I/M Program Costs

a. I/M Program Costs

The major cost components for the four-county and statewide options are summarized in Tables 5 and 6. The costs are identified as to state costs necessary to administer and conduct surveillance of the private-garage program, and operation and capital costs assigned to the private garage.

1. Four-County Option - It has been estimated that 671 private garages, distributed in the four counties as noted in Table 5, will actively participate in the I/M program. This will require a 10-year expenditure by the private garages of $4.0 million and $9.9 million for test equipment and facility operations, respectively. During this same period, the State will expend $4.9 million for capital, operation, and implementation costs. Total I/M expenditures by state and private garages for a 10-year program duration is estimated at $18.9 million.

   The private garage capital/expenditure of 4.0 million is the accumulated first time instrumentation costs of $3,000 and a 5 year replacement cost for a total of $6,000 per private garage - (6,000 x 671 = $4 million). The private garage-operation cost of 9.9 million are for the 671 private garages over the 10-year program at an operating cost per private garage over the 10 years of $14,800 or an average of $1,500 per year. Therefore, the total average cost per private garage per year is $2,200.

   The state costs of $4.9 million or an average of $40,000 per year over the 10-year program is for 3.2 million operating costs for administrative support analysis of data, prepare reports and administer the program including consumer protection, 1.2 million for quality control of 671 private garages, $200,000 for one time public information program, 1.2 million for quality control equipment, 8.5 thousand for office equipment, $78,000 for vehicle for complaint investigation

Table 5

COSTS OF SOUTH CAROLINA I/M PROGRAM - FOUR COUNTIES OPTION
($1,000 1978 Dollars)

CATEGORY	1982-1986		1987-1991		TOTAL	
	State	Private Garage	State	Private Garage	State	Private Garage
I Test Equipment Costs[a]	0	2,013.0	0	2,013.0	0	4,026.0
II Operating Costs						
Facility Operation	0	4,562.9	0	5,351.6[b]	0	9,914.5
Administrative Support	1,616.5	0	1,616.5	0	3,233.0	0
Quality Control	612.0	0	612.0	0	1,224.0	0
III Initial Implementation Costs	61.5	0	0	0	0	61.5
Public Information	200.0	0	0	0	0	200.0
IV Other Capital Costs						
Administrative Office Equipment	8.5	0	0	0	8.5	0
Quality Control Equipment	119.0	0	0	0	119.0	0
Consumer Protection	78.0	0	0	0	78.0	0
TOTAL	2,695.5	6,575.9	2,228.5	7,364.6	4,924	13,940.5
TOTAL STATE & PRIVATE GARAGE	9,271.4		9,593.1		18,864.5	

[a] Number of private garages participations in the program are:

Berkeley County	47
Charleston County	235
Lexington County	124
Richland County	265

[b] Facility operation costs increased to compensate for increase in the vehicle population.

Table 6

COSTS OF SOUTH CAROLINA I/M PROGRAM - STATEWIDE OPTION[a]
($1,000 1978 Dollars)

CATEGORY	1982-1986		1987-1991		TOTAL	
	State	Private Garage	State	Private Garage	State	Private Garage
I Test Equipment Costs[b]	0	9,405.0	0	9,405.0	0	18,810.0
II Operating Costs						
Facility Operation[c]	0	13,053.6	0	15,508.5	0	28,562.1
Administrative Support[c]	7,552.5	0	7,552.5	0	15,105.0	0
Quality Control[c]	2,859.3	0	2,859.3	0	5,718.6	0
III Initial Implementation Costs[c]	202.0	0	0	0	202.0	0
Public Information	200.0	0	0	0	200.0	0
IV Other Capital Costs						
Administrative Office Equipment[c]	41.1	0	0	0	41.1	0
Quality Control Equipment[c]	575.7	0	0	0	575.7	0
Consumer Protection[c]	377.4	0	0	0	377.4	0
TOTAL	11,808.0	22,458.6	10,411.8	24,913.5	22,219.8	47,372.1
TOTAL STATE & PRIVATE GARAGE	34,266.6		35,325.3		69,591.9	

[a] Costs are to the closest $100.

[b] 3,135 private garages would be participating in the program.

[c] Costs for statewide option are considered directly proportional to the number of stations participating in the program.

and software development for vehicle scheduling, and one time cost associated with vehicle scheduling.

2. Statewide Option - In contrast to the four county option, the total capital costs for 3,135 private garages at $6,000 per garage is $18.8 million. This will require an annualized cost for capital equipment $700 per year per private garage. The private garage operation costs over the 10-year period is $28.5 million or $9,000 per private garage. This amounts to $900 per private garage per year and a total cost per year for capital and operation costs of $1,600.

The statewide operation costs of each private garage is less because they will not inspect as many vehicles per garage as in the four county option. The operating costs per vehicle is equal for each option.

The state cost of $22.2 million or an average of $2.22 million per year over the 10-year program is to cover 1) 15.1 million for operating administrative costs to support analyses of data, prepare reports, administer the program, investigate complaints and consumer protection, $5.7 million for increased quality control of the 3,135 private garages, 2) initial implementation costs of $202,000 and $200,000 for public information, and 3) other capital costs of approximately 1 million consisting of $41,000 for administrative equipment, $575,000 for quality control equipment and $377,000 for consumer protection capital cost.

The state costs increase was considered to be proportional to the large increase of participating private garages which was a 4.7 fold increase over the four county options.

The total operating and capital cost for the statewide option program is approximately $69.5 million. The gross estimate under this option was to provide general comparative data only.

b. Comparison of State Manpower Requirements

Table 7 lists the State personnel requirements for the four-county area and the statewide program options. The State personnel requirements do not have a one-to-one correspondence to the number of vehicles because the minimum effort of program administration is independent of the number of vehicles. For example, the number of inspection agents is based upon a calibration check at each station every two weeks.

Program management responsibilities for either option will include: 1) vehicle test scheduling, 2) record maintenance, 3) establishment and review of emission test limits, 4) data analyses to determine inspection program effectiveness, 5) evaluation of current and future equipment needs, and 6) provision for future analyses and development. These program responsibilities will be coordinated by three key state personnel positions: 1) Quality Control Assistant Program Administrator, 2) Testing Assistant Program Administrator, and 3) Environmental Engineer. The specific responsibilities for each management position is outlined as follows:

1. Assistant Program Administrator (Quality Control) - Will manage the twice-monthly equipment calibration checks for all private-garage inspection centers; the statistical analysis of emission test data.

2. Assistant Program Administrator (Test) - Will be responsible for the efficient day-to-day operation of referee test stations.

3. Environmental Engineer - Is responsible for monitoring program effectiveness and evaluation of vehicle emission reduction.

3. Consumer Fee

In order to compute consumer fee, the program costs for the four-county and statewide options in Tables 5 and 6 were converted into annualized costs. This was done by amortizing capital-related (categories I, IV, and V) over 10 years of program operation. Results are presented in Tables 8 and 9. Cost of capital was assumed to be 6 percent.

Table 7. I/M STATE MANPOWER REQUIREMENTS

JOB CATEGORY	FOUR-COUNTY AREA	STATEWIDE
Program Administrator	1	1
Assistant Program Administrator (Quality Control)	1	1
Assistant Program Administrator (Testing)	1	1
Environmental Engineer	1	2
Statistician	1	2
Clerical	4	8
Secretaries	1	2
Inspection Agents	10	43
TOTAL	20	60

Table 8. ANNUALIZED COSTS OF I/M PROGRAM[a,b] - FOUR COUNTIES
(1978 DOLLARS)

CATEGORY	TOTAL AMORTIZED COST[c]	AVERAGE ANNUALIZED COST ($/YR)
I. Test Equipment Cost private garage	$2,013,000 x 0.2374 x 5^d + $2,013,000 x 0.2374 x 5^d = $4,779,900	$4,778,862/10 = $477,900
II. Operating Costs		
private garage		$9,914,500/10 = $991,500
state		$3,233,000 + 1,224,000/10 = $445,700
III. Initial Implementation Costs - state	$61,500 x 0.1359 x 10 = $83,600 $200,000 x 0.1359 x 10 = $272,000	(83,500 + 72,000)/10 = $35,600
IV. Other Capital Costs - state	(8,500 + 119,000 + 78,000) x 0.1359 x 10 = $279,300	$279,300/10 = $27,900 27,900
Total - State		$ 509,300
Private Garage		$1,469,400
State and Private Garage		$1,978,000

[a] All costs are rounded off to hundred dollars

[b] Basic cost data is taken from Table 5.

[c] Amortization factor (F) is determined by the formula

$F = \frac{2(1+i)^n}{(1+i)^{n-1}}$, where i is the cost of capital (=6%) and n is the number of years

For equipment amortization of 5 years, F = 0.2374
For capital amortization of 10 years, F = 0.1359

[d] The equipment life is considered to be 5 years, therefore, it is required to replace equipment after 5 years.

NOTE: Fee Calculation

$$\text{private garage share} = \frac{\$1,469,400}{622,200 \text{ vehicles}} = \$2.36$$

$$\text{state share} = \frac{\$509,300}{622,200 \text{ vehicles}} = \$0.81$$

TOTAL FEE $3.17

Table 9. ANNUALIZED COSTS OF I/M PROGRAM[a,b] - STATEWIDE
(1978 DOLLARS)

CATEGORY	TOTAL AMORTIZED COST[c]	AVERAGE ANNUALIZED COST ($/YR)
I. Test Equipment Cost private garage	$9,405,000 x 0.2374 x 5^d + $9,405,000 x 0.2374 x 5^d = $22,327,500	$22,327,500/10 = $2,232,700
II. Operating Costs		
private garage	$28,562,100 facility operating	$28,562,100/10 = $2,856,200
state		(15,105,000 + 4,718/500)/10 = $2,082,400
III. Initial Implementation Costs - state	$202,000 x 0.1359 x 10 = $274,500	$274,500/10 = $27,500
IV. Other Capital Costs state	(41,100 + 575,700 + 377,400) x 0.1359 x 10 = $1,351,100	$1,351,100/10 = $135,100
Total - State		$5,088,900
Private Garage		$2,245,000
State and Private Garage		$7,333,900

[a] All costs are rounded off to hundred dollars.

[b] Basic capital and operating cost data is taken from Table 6.

[c] Amortization factor (F) is determined by the formula.

$F = i(1 + i)^n/1 + i)^n - 1$ where i is the cost of capital (= 6%) and n is the number of years.
For equipment amortization of 5 years, F = 0.2374
For capital amortization of 10 years, F = 0.1359

[d] Equipment life is considered 5 years, therefore, it is required to replace equipment after 5 years.

NOTE: Fee Calculations

$$\text{private garage share} = \frac{\$5,088,900}{2,103,000 \text{ vehicles}} = \$2.42$$

$$\text{state share} = \frac{\$2,245,000}{2,103,000 \text{ vehicles}} = \$1.06$$

TOTAL FEE $3.48

The average consumer fee to defray the four-county I/M program cost was estimated to be $3.17 per vehicle (in 1978 dollars). The state's share is $0.81 while the private garages's share is $2.36. The fee is derived by dividing total annualized costs in 1978 dollars by the vehicle population of 622,200 in year 1986. The fee allows one retest of a failed vehicle.

The average consumer fee to defray the statewide option I/M program cost was estimated to be $3.48 (see Table 9). The state's share is $1.06, while the private garage's share is $2.42. The average vehicle population for the statewide option was 2,103,000 vehicles. The increased cost for the statewide option is because the costs of equipment and operations requrements of 3,135 participating private garages. The participating garages for the statewide program would be testing fewer vehicles then the participating stations in the four-county option.

It should be noted that the fee covers only the State's direct cost on the I/M program and certain indirect costs, such as utilities/supplies, office rental, etc. It is difficult to include all governmental indirect costs in this study without a detailed knowledge of the state's general accounting procedure.

4. Costs of Repair

The maintenance of the I/M program involves the repair of those vehicles which were identified as high emitters; the level of preventative maintenance requested by vehicle owners; and any unnecessary repairs by the service industry.

Recent Arizona I/M experience revealed that the average cost of repairs of failed vehicles was $23.20 during 1977 based upon average repair cost for 1968 to 1977 model years with market distribution set forth in Table 10. These costs ranged from zero for warranty repairs to over $600. for an engine overhaul. Table 10 presents the average cost of repairs for various model-year groupings in different facilities performing the repairs.

Table 10. ARIZONA SERVICE INDUSTRY REPAIR COST FOR FAILED VEHICLES

TYPE FACILITY	1964-1967	1968-1977	1964-1977	MARKET SHARE PERCENTAGE
Franchised dealers	$41.25	$26.82	$27.97	13
Service stations	23.06	19.81	21.14	15
Merchandisers	15.53	20.29	19.43	3
Tune-up specialists	36.19	22.86	24.72	3
Independent garages	21.33	27.46	26.79	27
"Do-it-yourselfers"	14.27	20.61	19.08	39

Source: Ref. 2.

Moreover, Table 11 presents vehicle percent contribution to various repair cost categories for Arizona, Oregon, and New Jersey. Again the repair costs are less than $10 for 29.8 to 66 percent of the vehicles tested. Lower repair costs are attributed to carburetor adjustments, rather than expensive tune-ups or engine repairs. The median value of $15 in the Arizona repair costs would indicate when comparing it to the average cost of $23.20 that the majority of vehicles have low repair costs and a few vehicles may have high repair costs.

Table 11. REPAIR COST SUMMARY FOR EXISTING I/M PROGRAMS

ITEM	ARIZONA	OREGON	NEW JERSEY
Repair Costs			
Less than $10	44%	64%	29.8%
$10 to $25	24%	21%	26.4%
$25 to $50	20%	8%	22.1%
$50 to $100	10%	5%	16.1%
More than $100	2%	2%	5.6%
Number of Vehicles	2,000	1,400	1,600
Median Repair Costs	$15	$8	$20
Percent of Repairs less than average cost	64%	71%	65%

Ref. 8

Other studies, however, indicated the average repair cost would be approximately $36. (in 1977 dollars). (Ref. 3, 4, 5, 6.) Some states have placed a cost ceiling on the amount of repair.

5. Emission Reduction Benefits

The levels of emission reduction that result from the implementation of I/M programs depends on the number of vehicles inspected, stringency factor*, function, and also on the travel characteristics in the county where the vehicles are registered.

The calculation of emission reduction as a result of I/M implementation was based on results obtained from the EPA-supported MOBILE 1 computer program. This program enables the user to apply I/M program credits to emission factor estimates by inputting a stringency factor and vehicle model-year applicability. Emission levels developed by MOBILE 1 program, presented in Tables 12 and 13, detail HC/CO emission levels without I/M; with I/M; and percent emission reduction from I/M implementation; for county and statewide geographic options.

This information was provided for 1982 and 1987 I/M program years using 1977 as a base year. The second column for HC and CO shows total emissions in 1977. The third and sixth columns show emissions expected in 1982 and 1987 without an I/M program. The lower figures for both years are attributable to the Federal Motor Vehicle Emission Control Program (FMVCP). The fourth and seventh columns show the amount of emission reduction that would occur with FMVCP and an I/M program. The fifth and eighth columns show the actual percent emission reduction that may be achieved through implementation of an I/M program. In all instances, the percent reduction for each county closely approximates percent reduction values achieved over the entire state.

6. Fuel Economy Benefits

One of the important benefits of I/M programs, in addition to the reduction in vehicular emissions, is fuel conservation. A properly tuned engine operates with greater efficiency, and therefore, consumes less fuel. This improvement in fuel economy varies somewhat from one program to another but most sources agree up to a 10-percent fuel economy improvement can be expected between the failed and maintained vehicles.

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*Stringency factor refers to the percentage of total vehicles tested in an I/M program, in a given time period, that fail inspection and are required to have maintenance performed.

Table 12. HC EMISSION REDUCTION WITH AND WITHOUT IMPLEMENTATION OF I/M PROGRAM FOR 1977 (Base Year), 1982, AND 1987 (Tons Per Year)

COUNTY	1977	1982			1987		
	WITHOUT I/M	WITHOUT I/M	WITH I/M	% REDUCTION	WITHOUT I/M	WITH I/M	% REDUCTION
1. Lexington	5,961	3,962	3,748	5	2,313	1,793	22*
2. Richland	10,376	6,148	5,790	6	3,499	2,670	24*
3. Berkeley	2,421	1,527	1,434	6	919	697	24*
4. Charleston	9,205	5,335	5,028	6	2,920	2,216	24*
Total	27,963	16,972	16,000	6	9,651	7,376	24*
Statewide	89,662	56,086	52,785	6	31,870	24,358	23*

SOURCE:: Ref. 6

*Although the 1987 percent reduction does not meet the EPA reduction of 25 percent as specified in Reference 1, the percent reduction could be within the error potential of the MOBILE1 program and the State of South Carolina should not have any difficulty in meeting the required percent reduction with the planned I/M program.

Table 13. CO EMISSION REDUCTION WITH AND WITHOUT IMPLEMENTATION OF I/M PROGRAM FOR 1977 (Base Year), 1982, AND 1987 (Tons Per Year)

COUNTY	1977	1982			1987		
	WITHOUT I/M	WITHOUT I/M	WITH I/M	% REDUCTION	WITHOUT I/M	WITH I/M	% REDUCTION
1. Lexington	43,973	38,548	32,552	16	25,903	17,459	33
2. Richland	79,829	60,983	51,112	16	39,160	25,944	34
3. Berkeley	17,581	14,684	12,278	16	10,116	6,609	35
4. Charleston	71,793	53,356	44,626	16	32,715	21,456	34
Total	214,176	167,571	140,568	16	107,894	71,468	34
Statewide	683,540	552,835	463,754	16	356,300	236,010	34

SOURCE: Ref. 6

An I/M program is to give an incentive to motorists to maintain their cars better than they normally would in the absence of I/M. This maintenance would increase vehicle-life and prevent problems such as vehicle stalling.

A 3.8 percent fuel economy improvement, per failed vehicle per year (as established from California programs), was used in this study to calculate fuel and dollar savings for the I/M program options. As shown in Table 14, the four-county I/M option would save 5.48 million gallons of fuel in 1982 and 4.07 million gallons in 1987. At $0.70 per gallon, vehicle owners would save $3.84 million and $2.85 million for 1982 and 1987, respectively. If coverage is extended to include the entire state, motorists would save 18.10 million gallons in 1982 and 13.45 million gallons in 1987. This amounts to $12.67 million and $9.41 million for 1982 and 1987, respectively.

Table 14. ESTIMATED ANNUAL FUEL ECONOMY BENEFITS FOR FAILED VEHICLES[a]

	1982 SAVINGS[b]			1987 SAVINGS[c]		
OPTION	Fuel[d] Mil. Gal	$ Million	Per Vehicle	Fuel[d] Mil. Gal	$ Million	Per Vehicle
1. Four-County (Lexington, Charleston, Berkeley, Richland)	5.48	$ 3.8	$7.14	4.07	$2.85	$4.46
2. Statewide	18.10	$12.67	$7.14	13.45	$9.41	$4.46

[a] See Section 4-D of the final report for computation details.

[b] Fleet average fuel efficiency is assumed to be 15 miles per gallon.

[c] Fleet average fuel efficiency is assumed to be 24 miles per gallon.

[d] Average miles traveled per year is 11,500 miles per year.

In terms of fuel savings per vehicle, it would be $7.14 in 1982 and $4.46 in 1987. Less fuel savings per vehicle in 1987 is anticipated because of higher fuel efficiency of automobiles. Moreover, the motorist who repairs his failed vehicle will realize a saving in fuel cost as an offset to the repair cost.

7. Indirect Impacts and Political Issues

In addition to the primary benefits of reducing vehicular emissions, fuel savings, and improving air quality, I/M programs have indirect benefits and bearing on political issues. To discover what the potential benefits and poltical issues might be, other I/M programs were reviewed.

a. Indirect Benefits

There are several indirect benefits that do not relate to specific options but would result from the implementation of any I/M program option. These include the following:

- Improved health benefits (less respiratory problems, etc.)
- Improved vehicle performance and vehicle life
- Increased agricultural production
- Reduction of airborne particulates
- Reduction of sulfur oxides, carbon monoxide, ozone, and nitrogen oxides
- Improvement in visibility
- Conservation of energy

The improvement in air quality in those areas where the NAAQS are currently exceeded are likely to have some benefits in the health of the affected population.

The amount and nature of the benefits would depend on the severity of air pollution prior to the implementation of the I/M program, and the amount of reduction in air pollution resulting from I/M. However, a recent publication

"Clean Air for South Caroline - How Our State Stands", identified several areas throughout the State that experienced 300 to 350 days of stagnant weather conditions.

b. Political Issues

Political issues surrounding an I/M program are:

- Impacts on low-income citizens
- Potential overcharging for repairs and performance of unnecessary repair work
- Problems of conflict of interest and uniformity of inspection in the private-garage approach

I/M programs have the potential of placing a burden on low-income citizens by forcing them to make expensive repairs for failed vehicles. This could force low-income people who own older vehicles to make needed repair that exceed the value of the vehicle. This problem has been reduced by instituting repair cost ceilings. Thus, if the cost of the repairs needed to meet the standard exceed a cost ceiling, then the vehicle could receive an inspection waiver. A cost ceiling, if implemented, could create administrative problems.

The problem of dealing with repair overcharging or unnecessary repair work can be dealt with in several ways. Some states have instituted recommended repair procedures that are specified for various emission failure problems. These procedures range from an idle adjustment to a low emission tune-up. Mechanic training programs will result in a higher level of repair competence and motivation. Consumer protection programs can be designed to identify those garages that charge significantly more than the average repair cost or identify garages generally drawing numerous consumer complaints. Such procedures can be relatively informal or can be tied in with formal licensing of garages and mechanics.

The options with inspection, as well as repair, in licensed private garages may pose quality assurance and consumer protection problems. With a large number of garages having emission analyzers of varying degrees of quality, and with less uniform supervision, there will probably be less uniformity of the inspection in private garages. Moreover, there is an inherent conflict of interest in having the same garage conduct both the testing and maintenance phase of I/M.

Public Information Program - Many questions raised by I/M implementation can be properly addressed through a well-designed and comprehensive public information program. It can help to eliminate adverse public criticism by stressing the purpose, objectives, benefits, and operation of I/M. Emphasizing the checks and balances (e.g., quality assurance) designed into the I/M program, and health benefits from emission reductions, will alleviate many problems associated with the implementation procedure.

A public information program can address other benefits to the vehicle owner. Improvements in fuel economy, vehicle performance and longevity are important to vehicle owners. Control of vehicles that emit annoying quantities of smoke, and assurances that I/M requirements will extend to all vehicles, are important points to stress.

This can be accomplished by effective use of advertising techniques that utilize the mass communication media (e.g.; radio, television, newspapers, etc.), information centers, education programs, citizen group contacts, etc. In the early stages of I/M implementation, initial program information should explain the following:

- Need for an I/M program
- Explanations that specify derived benefits from automotive emission inspection and maintenance
- Cost and benefit of an I/M program for in-use vehicles
- Explanations of the inspection procedure

Supplemental information is required after the public has accepted the need to understand the concepts of I/M. This additional information includes:

- The location of test facilities and private garage responsibilities in the program
- Instructions and fee requirements
- Explanation of basic idle test requirements and retest requirements and conditions
- Importance for allowing time for repair and retest, or considerations for waiver (if implemented)
- Explanation of complaint referral system
- Explanation of area covered by I/M program
- Explanation of maximum repair level, average repair, carburetor and ignition functions and major repair problems

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Section 2

INTRODUCTION

The purpose of this document is to present information on the possible use of vehicle inspection/maintenance (I/M) as a strategy for reducing air pollutant levels in the State of South Carolina. The format of the report was developed with the specific intent of allowing distribution to a wide audience, including both technical and nontechnical personnel. Depending on the background of the reviewer and his familiarity with I/M, it will be necessary to examine all or only certain sections of the document. Section 1 of the report presents an Executive Summary of the costs and benefits associated with potential I/M programs for South Carolina. This section will be particularly useful for persons with a good initial understanding of I/M and limited time for review. Section 3 is made up of a series of technical memoranda which give generalized background information on the following topics:

- The National Ambient Air Quality Standards (NAAQS)--their origin, basis and health implications, particularly with respect to photochemical oxidants and carbon monoxide.

- Geographic description of the nonattainment status of the State with respect to oxidant and carbon monoxide air quality standards.

- Requirements of the Clean Air Act Amendments of 1977 as they relate to I/M, including a discussion of the Federal sanctions which may be imposed if states do not comply with these requirements.

- General description of the effectiveness of an I/M program in the reduction of hydrocarbon and carbon monoxide from vehicular sources.

- Testing program (emission testing program with a 30 to 35 percent failure rate).

- Ownership of test lanes and equipment (private garage with safety inspection program).

- Test mode (idle).

Section 4 gives more detailed descriptions of the analysis work that was performed for this project. It includes an expanded explanation of each of the various facets of an I/M program for South Carolina. The section also discusses the methodology used to compute costs and benefits, and provides information on the particular requirements of certain program issues such as consumer protection, mechanic training, legislation, etc. This technical information is of use to those governmental agencies which will be responsible for implementation of a certain facet of the I/M program.

Recent national interest in I/M as a control measure for vehicle emissions was generated by provisions of the Clean Air Act Amendments of 1977. Briefly, in accordance with the Amendments, all areas of the country are to achieve ambient air quality standards by 1982 through the implementation of Air Quality Management Planning. One of the means by which this 1982 goal can be reached is through implementation of I/M. Under certain circumstances, an extension of compliance until 1987 can be granted. In this situation, however, the implementation of I/M is mandatory.

Four counties in the State of South Carolina have been designated by EPA as nonattainment areas. Three counties are currently designated as CO nonattainment. The State of South Carolina has been investigating a number of pollution control measures to attain standards in these areas and, as a portion of this effort, has directed Systems Control, Inc. (SCI) to provide data on I/M implementation.

The scope of the work performed by SCI during Task II was primarily focused on the cost/benefit analysis of the four counties designated by the

State of South Carolina; Berkeley, Charleston, Lexington and Richland. The scenario studied was as follows:

- Private garage-operated
- Idle-mode check for HC and CO (with safety inspection)
- 30 to 35 percent stringency factor
- Vehicle registration enforcement
- Area coverage is for the four noted counties (Note - a gross analysis was completed on the entire state)

Task 1 of the program outlined certain program options that allow for Federal Appendix "N" credits. The Appendix N requirements and associated program options were identified as follows:

- Ensure regular periodic inspections - (Reference Item(c),(i), Appendix N)
  - Vehicle registration process
  - Clean air sticker program
- Inspection failure criteria - Idle mode test, 30 to 35 percent stringency factor administered by either of the following options (Reference Item(c),(ii), Appendix N):
  - Government-operated
  - Contractor-operated
  - Private garage-operated

- Ensure that necessary maintenance is performed - (Reference Item(c),(iii), Appendix N)
  - Sanctions against owner by denial of vehicle registration and/or imposing fines.
  - Sanctions against repair facilities by imposing a fine and/or loss of license.
  - Retesting failed vehicles.
  - Certification of repair facilities to ensure that they have the proper equipment, necessary parts, and adequate knowledge for emission control repair.

- Capital Investment Per Station
  -$3,000 - Cost of emission testing and auxilary equipment

- Operations Throughput Time
  -3.75 minutues

- Mechanics Costs (including overhead)
  -$18 per hour

- Station inspection load factor capability - 10 percent. NOTE: In the four county area with safety inspection stations the load factor for emissions testing is about 3 percent.

- Emissions for statewide option were developed by extrapolating the four county data.

- Cost of capital is 6 percent for the state.

- The state personnel benefits including sick leave, vacation, retirement, insurance, holidays, etc., is 25 percent of base rate.

- Fuel costs is $.70 per gallon.

- Inflation rate is 7 percent. To convert from 1978 to 1983, a compound factor of 1.403 must be used.

- Indirect costs reflecting the cost to consumers for waiting time at inspection lanes and cost of transportation to and from the inspection and repair facilities were ignored.

- Average miles traveled per year for LDVs is 11,500 miles per year.

- Failed vehicles consumed 3.8 percent more fuel than the certified vehicle.

- Assumed miles per gallon fleet average for LDVs is 15 miles per gallon (1982), 24 miles per gallon for 1987 LDVs.

- Enforcement measures to ensure that vehicles are not intentionally readjusted or modified after inspection. (Reference Item(c),(iv), Appendix N).
  - Highway Patrol spot checks
  - Random Sampling Reinspection

The appendices provide information on the correlation of short tests to the FTP, a glossary of terms relating to I/M program, and the reprints of Federal Register Appendix N, and the memorandum from the United States EPA to regional administrators.

Data utilized in this study were provided by the State of South Carolina Department of Highway and Public Transportation. The data represent the most current information available at the time of the study. It should be stressed, however, that the methodology utilized in this study was derived from past experiences with other I/M programs, and that the authors possess only a superficial knowledge of the structure of the South Carolina State government. The actual implementation of an I/M program for the State will require further in-depth analysis to determine particular locations for test sites, emission failure criteria, designated agency responsibilities, test station design and other considerations.

A. ASSUMPTIONS

The methodology used in this Task 2 report was based upon the following assumptions:

- The program operation is over a period of 10 years.

- The State would assume that cost of purchasing test equipment and lease them to private garages.

- Vehicle Population Growth
  - 1976 to 1982 - 4 percent
  - 1982 to 1992 - 3.5 percent.

Section 3

BACKGROUND TECHNICAL MEMORANDA

A. National Ambient Air Quality Standards

B. Nonattainment Areas for Photochemical Oxidants and Carbon Monoxide in the State of South Carolina

C. Clean Air Act Amendment Requirements for I/M Programs

D. I/M Program Effectiveness in Reducing Hydrocarbon and Carbon Monoxide Emissions from Light-Duty Vehicles

E. Testing Program with a 30 to 35 Percent Failure Rate

F. Administrative Program Options

G. Idle-Mode Test

A. NATIONAL AMBIENT AIR QUALITY STANDARDS

1. Origin of the Standards

The basis for the development of the National Ambient Air Quality Standards (NAAQS) was established by Congress through the Air Quality Act of 1967. The Act, as originally adopted, required the Secretary of Health, Education and Welfare to develop and issue criteria of air quality which were requisite for the protection of the public health and welfare. Under the 1967 Act, the states were then expected to develop air quality standards and plans for the implementation of the standards. In May 1971, however, the EPA promulgated national ambient air quality standards for six major pollutants. The Standards as originally adopted are shown in Table 3-1. In subsequent revisions to the Standards by the EPA, secondary standards for certain pollutants were also adopted. These secondary standards were established at levels deemed necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant. The secondary standards were set to prevent harmful effects on animals, vegetation, weather and visibility, and to preserve a certain "quality of life." The current primary and secondary standards are given in Table 3-2.

The latest revisions to the NAAQS have resulted from the 1977 Amendments to the Clean Air Act. Section 109 of the Act was amended to require the EPA to establish an independent scientific committee to review air quality criteria and the NAAQS not later than December 31, 1980 (at subsequent intervals not exceeding 5 years), and recommend revisions in the criteria and standards as may be appropriate. The EPA was also directed to promulgate short-term primary standards for NO_2 (less than 3 hours within 1 year).

a. Health Effects of Air Pollutants

The major air pollutants which are of significance are characterized as follows:

- Particulate matter is generally any matter (less than 500 microns), whether solid or liquid, that is dispersed in the air. Studies

Table 3-1.
NATIONAL AIR QUALITY STANDARDS
ESTABLISHED IN 1971

Pollutant	Level not to exceed	
	µg/m³	ppm
SO_2	80[a]	0.03
	365[b]	0.14
Particulate matter	75[c]	
	260[b]	
Carbon monoxide	10[d]	9
	40[e]	35
Photochemical oxidants	160[e]	0.08
Hydrocarbons	160[f]	0.24
Nitrogen oxides	100[a]	0.05

[a] Annual arithmetic mean.

[b] Maximum 24-hr concentration not to be exceeded more than once a year.

[c] Annual geometric mean.

[d] Maximum 8-hr concentration not to be exceeded more than once a year.

[e] Maximum 1-hr concentration not to be exceeded more than once a year.

[f] Maximum 3-hr concentration (6-9 a.m.) not to be exceeded more than once a year.

Table 3-2.
FEDERAL AMBIENT AIR QUALITY STANDARDS

POLLUTANT	AVERAGING TIME	FEDERAL	
		Primary	Secondary
Carbon Monoxide	8 hrs	9.0 ppm^a (10 mg/m^3)	Same as primary standards
	1 hr	35.0 ppm (41 mg/m^3)	
Nonmethane hydrocarbons	6-9 a.m.	0.24 ppm^a (160 μg/m^3)	Same as primary standards
Photochemical oxidants	1 hr	0.08 ppm^a (160 μg/m^3)	Same as primary standards
Nitrogen dioxide	Annual	0.05 ppm (100 μg/m^3)	Same as primary standards
Particulate	Annual geometric Mean	75 μg/m^3	60 μg/m^3
	24 hrs	260 μg/m^3	150 μg/m
Sulfur dioxide	Annual arithmetic Mean	0.03 ppm (80 μg/m^3)	0.02 ppm (53 μg/m^3)
	24 hrs	0.14 ppm (373 μg/m^3)	. . .
	3 hrs	. . .	0.50 ppm (1334 μg/m^3)

[a] Not to be exceed more than one per year.

ppm -parts per million
mg/m^3-milligrams per cubic meter
μg/m^3-micrograms per cubic meter

indicate an association between particulate matter and certain health effects, especially injury to the respiratory system. Other problems associated with high concentrations of particulate matter are impaired visibility, increased corrosion of some metals, and damage to plants and vegetation.

- Carbon monoxide (CO) emissions arise primarily from incomplete combustion of carbonaceous fuels. Factors such as oxygen concentration, flame temperature, gas residence time, and combustion chamber turbulence are important variables that affect the CO concentrations in exhaust. Carbon monoxide is absorbed into the blood stream within the respiratory tract and reacts primarily with the hemoglobin in red blood cells. This decreases the oxygen-carrying capacity of the blood reducing the amount of oxygen transported to vital tissues.

- Hydrocarbons are primarily associated with processing and use of petroleum products. They constitute the major portion of the reactive organic substances that produce photochemical oxidant. The only direct effect attributable to high ambient levels of hydrocarbons (i.e., ethylene) is vegetation damage. Polynuclear hydrocarbons, some of which are carcinogenic--such as benzo( ) pyrene-- are primary pollutants arising from a variety of combustion processes. Auto exhaust is a major source of atmospheric polynuclear aromatic hydrocarbons.

- Photochemical oxidants are produced in the atmosphere when reactive organic substances (mainly hydrocarbons) and nitrogen oxides are exposed to sunlight. Ozone is the major reaction product of these oxidants. Photochemical oxidants at certain concentrations can cause irritation of the mucous memberances, damage to vegetation, and deterioration of materials. They affect the clearance mechanism of the lungs and alter resistance to respiratory bacterial infection.

- Nitrogen oxides (NO_x), namely nitrogen dioxide (NO_2) and nitric oxide (NO), are formed during combustion processes in chemical reactions involving atmospheric nitrogen and fuel-bound nitrogen. The amount formed depends on the temperature of both reactants and products, and the length of time favorable conditions persist for the oxygen-nitrogen reactions. Nitric oxide has not been shown to have any adverse effects on health or welfare. However, there are several atmospheric reactions which can lead to the oxidation of nitric oxide to nitrogen dioxide, NO_2. Nitrogen dioxide has been associated with a variety of respiratory diseases and is also essential to the production of photochemical smog. Corrosion of electrical components and vegetation damage have been linked to NO_2 at high concentrations.

- Sulfur dioxide (SO_2) is produced by the combustion of fuel in power-generating facilities as well as in automobiles. The effects of SO_2 on health are related to irritation of the respiratory system at low concentrations, destruction of the upper respiratory cilia carry capacity at high concentrations, and reduction to viral resistance in the presence of particulates. Research has also been conducted to study the synergistic effects of particulates and SO_2 in combination as related to corrosion damage.

Tables 3-3 through 3-6 describe in further detail the effects of air pollutants.

Table 3-3.
EFFECTS OF AIR POLLUTION

A. Biological Effects on Human Subjects

Pollutant	Effect	Single concentration	Average concentration	Exposure	Other	Reference
Carbon monoxide	Epidemiological significance	30 ppm		8 hours	Synergistic in PO_2 depression	4
	Discomfort	900 ppm	900 ppm	1 hour		3
		100 ppm	100 ppm	9 hours		3
	Severe distress	100 ppm	100 ppm	15 hours		3
	Lethal	4 000 ppm		<1 hour		-
Hydrocarbons					$HC + O_3 \rightarrow$ tumorigen	
Inorganic particulates	Pulmonary sclerosis					
Nitrogen dioxide	Lethal Mild accelerator of lung tumors	500 ppm	500 ppm	48 hours	NO_2 + microorganisms (pneumonia) + HNO_3 (bronchiolitis, fibrosa obliterans) + tars (smokers, lung cancer)	1

Table 3-3.

EFFECTS OF AIR POLLUTION (Continued)

Pollutant	Effect	Single concentration	Average concentration	Exposure	Other	Reference
Ozone	Odor	<0.02–0.05 ppm		Instantaneous	Accelerated aging	6,7
	Pulmonary function		0.60–0.80 ppm	120 minutes	Reduction in steady state pulmonary diffusing capacity (DL_{co})	8
	Discomfort		0.05–0.10 ppm	13–30 minutes		6,7
	Mucosa		0.30–1.00 ppm	15–60 minutes	O_3 + microorganisms (lung-tumor accelerator)	6,9
	Severe distress		1.5–2.0 ppm	120 minutes	Impaired lung function: severe fatigue, chest pains; coughing for 2 weeks	10
	Histological		0.2–0.25 ppm	30 minutes	Sphering of red blood cells	11
	Other		0.60–0.80 ppm	120 minutes	Substernal soreness and tracheal irritation 6–12 hours after exposure, disappearing within 24 hours	8

Table 3-3.

EFFECTS OF AIR POLLUTION (Continued)

Pollutant	Effect	Single concentration	Average concentration	Exposure	Other	Reference
PAN^a	Pulmonary function	>0.30 ppm		5 minutes	Significant increase in oxygen uptake during light exercise	12
Sulfur dioxide, sulfur trioxide	Odor	0.5–0.7 ppm		1 second		13
	Taste	0.3–0.1 ppm		A few seconds		13
	Epidemiological significance	0.20 ppm	0.015 ppm	24 hours (annual average)		13
	Pulmonary function	1.6 ppm		10 minutes	SO_2, SO_3 + particulates aggravate lung disease	13
	Discomfort Severe distress	5 ppm 5–10 ppm		10 minutes (sensitive subjects)		13
Total oxidant	Pulmonary function		0.138 (mean of daily maxima NKI)	1 week	^{b}	14

Table 3-3.

EFFECTS OF AIR POLLUTION (Continued)

Pollutant	Effect	Single concentration	Average concentration	Exposure	Other	Reference
Suspended particulate and settleable matter	Epidemiological significance		500 μg/m³	24 hours	In presence of 24-hour August SO_2 concentration of 0.15 ppm	18,19
Suspended particulate and settleable matter (Cont.)	Discomfort		≥150 mg/m³ 1.5 mg/cm³	24 hours 30 days	Continuous source, dustfall	20
	Other				Particles <5 μm and concentration >10 particles/cm³ do not have complete elimination from lungs	21

Table 3-3.
EFFECTS OF AIR POLLUTION (Continued)

B. Biological Effects on Animals

Pollutant	Effect	Subject	Single concentration	Average concentration	Time of average	Other	Reference
Nitrogen dioxide	Odor		5 ppm		5 seconds		2
	Discomfort	Mice, rabbits, cats	10–20 ppm				2
	Mucosa	Mice, rabbits, cats	10–20 ppm				2
	Severe distress	Mice, rabbits, cats	20–100 ppm				2
	Pathological	Mice	8 ppm	8 ppm	8 weeks		3
	Lethal	Man	500 ppm	500 ppm	48 hours		1
Nitrogen oxide	Lethal	Mice	2 500 ppm		6–7 minutes		2
		Mice	320 ppm		60 minutes		4
PAN[a]	Lethal	Mouse		105 ppm	120 minutes		5
Sulfur dioxide	Lethal	Rabbit		50 ppm	30 days/6 hour day		6
	Central nervous system	Animal	0.20 ppm		10 seconds several times		6
	Other	Animals		1 000 ppm	8–16 hours	100% kill	6
Total oxidant	Histological	Mouse		>0.40 ppm (NKI)	2–3 hours		7
	Pathological	Mouse		0.40 (mean of daily maxima NKI)	16 months		8

Table 3-3.
EFFECTS OF AIR POLLUTION (Continued)

C. Biological Effects on Vegetation

Pollutant	Subject	Effect	Single concentration	Average concentration	Time of average	Other	Reference
Nitrogen dioxide	Plants	Plant leaf symptoms	3 ppm	2.5	4 hours	Symptoms similar to SO_2. Irregular, white, or brown collapsed lesion on intercostal tissue and near leaf margin	9, 10
Ozone	Plants	Palisade of leaf is affected. Growth suppression and changes in pigmentation, such as flecks, stippling, bleaching, and bleached spotting, occur. There is early abscission, and conifer needles become brown and necrotic. Time, 4 hours; concentration, 0.03 ppm. See References 11-21					
Peroxyacetyl nitrate (PAN)†	Plants	Spongy cells of leaves are affected. Glazing, silvering, or bronzing occurs on the lower leaf surface. Time, 6 hours; average concentration, 0.01 ppm. See References 20, 21, 23, and 24					
Sulfur dioxide		Plant leaf symptoms		0.28 ppm	24 hours	Bleached spots, bleached areas between veins, bleached margin	10, 26
		Plant chlorosis	>0.25 ppm	0.03 ppm	Annual average		10, 26
		Plant growth altered		0.05–0.20 ppm	24 hours; for	Growth suppression, early	10, 26

Table 3-3.
EFFECTS OF AIR POLLUTION (Continued)

Pollutant	Subject	Effect	Single concentration	Average concentration	Time of average	Other	Reference
					growing season	abscission, reduction in yield	
Total oxidant	Plants	See References 11, 14–16, 27				Affects meso-phyll cells	

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Table 3-4.

VISUAL RANGE IN A POLLUTED ATMOSPHERE

Relation Between Equivalent Visual Range and Particle Concentration

Mass concentration, $\mu g/m^3$	Scattering coefficient due to aerosol, b_{scat}/m	Equivalent visual range, km	Equivalent visual range, miles
10	0.3×10^{-4}	120.0	75.00
30	1.0×10^{-4}	40.0	25.00
100	3.3×10^{-4}	12.0	7.50
300	10.0×10^{-4}	4.0	2.50
1 000	33.0×10^{-4}	1.2	0.75

Note: These experimental data are in substantial agreement with other reported measurements; see *Air Quality Criteria for Particulate Matter*, AP-49, National Air Pollution Control Administration, January 1969.

Source: R. J. Charlson, "Atmospheric Aerosol Research at the University of Washington," *J. Air Pollut. Contr. Assn.*, *18*:652, 1968.

Table 3-5.

AIR POLLUTION DAMAGE TO VARIOUS MATERIALS

Materials	Typical manifestation	Measurement	Principal air pollutant	Other environmental factors
Metals	Spoilage of surface, loss of metal, tarnishing	Weight gain of corrosion products, weight loss after removal of corrosion products, reduced physical strength, changed reflectivity or conductivity	SO_2, acid gases	Moisture, temperature
Building materials	Discoloration, leaching	Not usually measured quantitatively	SO_2, acid gases, sticky particulates	Moisture, freezing
Paint	Discoloration, softened finish	Not usually measured quantitatively	SO_2, H_2S, sticky particulates	Moisture, fungus
Leather	Powdered surface, weakening	Observation, loss of tensile strength	SO_2, acid gases	Physcial wear
Paper	Embrittlement	Decreased folding resistance	SO_2, acid gases	Sunlight
Textiles	Reduced tensile strength, spotting	Reduced tensile strength, altered fluidity	SO_2, acid gases	Moisture, sunlight, fungus
Dyes	Fading	Fading by reflectance measurements	NO_2, oxidants, SO_2	Sunlight, moisture
Rubber	Cracking, weakening	Loss in elasticity, increase in depth of cracks when under tension	Oxidants, O_3	Sunlight
Ceramics	Changed surface appearance	Changed reflectance measurements	Acid gases	Moisture

Source: J.E. Yocom and R.O. McCaldin, in *Air Pollution* A. C. Stern, Ed., Vol. 1, Academic Press, New York, N.Y., 1968, p. 624.

Table 3-6.
ADDED COSTS OF LIVING IN DIRTY ENVIRONMENT

Downtown Steubenville, Ohio, 383 $\mu g/m^3$
Versus Uniontown, Pa., 115 $\mu g/m^3$
Particulates for 28 Activities, 1960

	Income group[a]	Extra cost per family Do-it-yourself	Extra cost per family Non-do-it-yourself
Inside maintenance	A	$ 29	$162
	B	44	227
Outside maintenance	A	21	49
	B	337	368
Laundry and cleaning	A	27	79
	B	129	186
Hair and facial care		9	48
Totals, per family			
In private homes	A	86	338
	B	519	829
In apartments (no inside painting or decorating, no outside maintenance)	A	47	263
	B	158	423

[a] A–Annual income under $8 000.
B–Annual income, $8 000 or more.

Source: *Interstate Air Pollution Study*, U.S. Department of Health, Education, and Welfare, Robert A. Taft Sanitary Engineering Center, Cincinnati, O., 1966.

B. NONATTAINMENT AREAS FOR PHOTOCHEMICAL OXIDANTS AND CARBON MONOXIDE IN THE STATE OF SOUTH CAROLINA

Recently, the South Carolina Environmental Protection Agency had identified two geographic areas as air quality nonattainment regions. The first geographic area, located in central South Carolina, includes Richland and Lexington Counties (Figure 3-1). This area was developed using measured oxidant data from existing monitors in Richland, and then extrapolated to Lexington County. The CO problem is localized within the boundaries of Richland County.

The second geographic area, identified as an oxidant nonattainment region, includes Charleston and Berkeley Counties. This area was not developed from air quality data, but rather was identified by the EPA using population criterion such that any metropolitan area with a population exceeding 200,000 is considered as a nonattainment area.

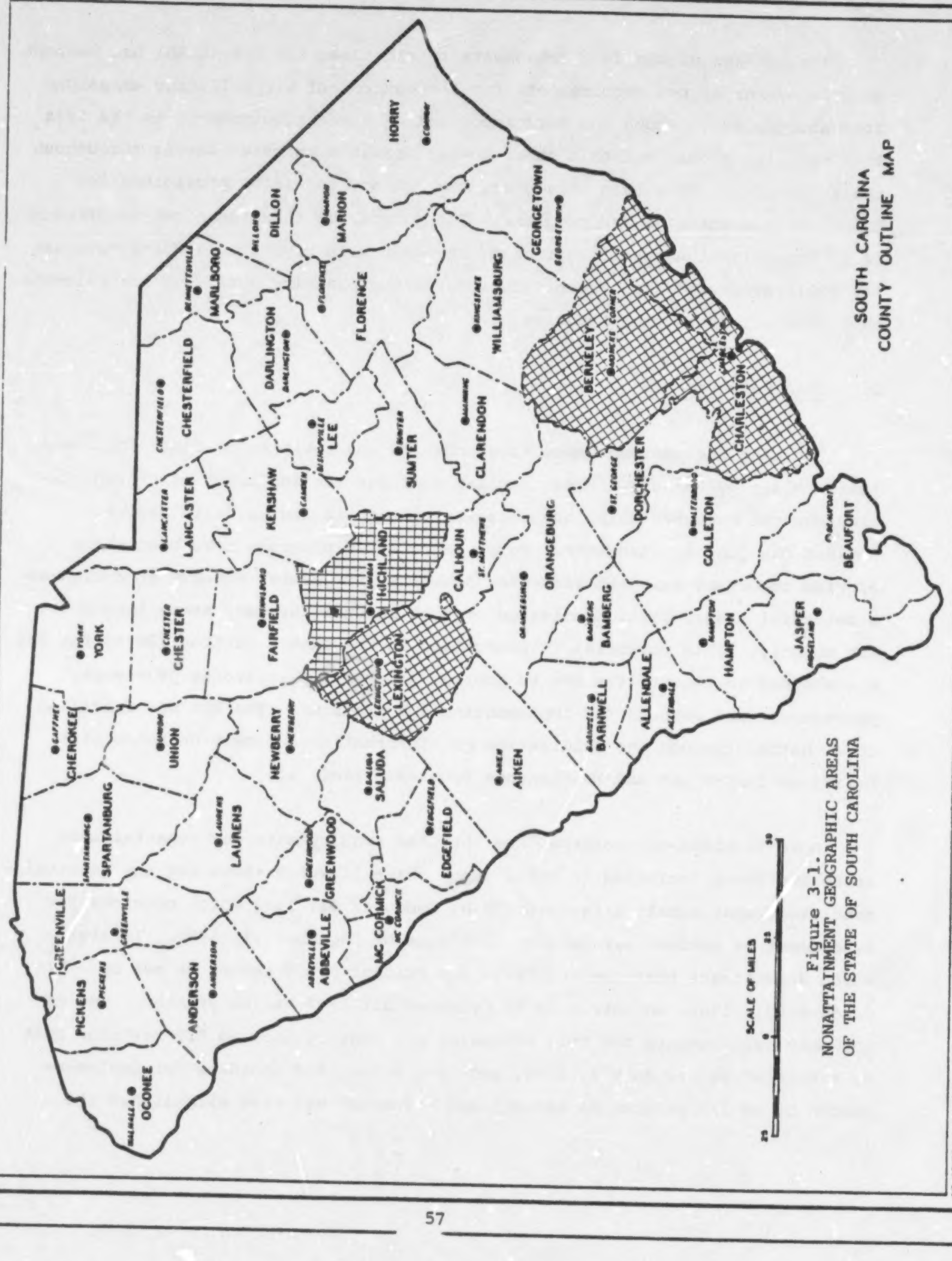

SOUTH CAROLINA
COUNTY OUTLINE MAP
OCONEE
PICKENS
GREENVILLE
SPARTANBURG
CHEROKEE
YORK
ANDERSON
LAURENS
UNION
CHESTER
LANCASTER
CHESTERFIELD
MARLBORO
DILLON
HORRY
MARION
FLORENCE
DARLINGTON
LEE
KERSHAW
FAIRFIELD
NEWBERRY
ABBEVILLE
GREENWOOD
McCORMICK
SALUDA
EDGEFIELD
LEXINGTON
RICHLAND
SUMTER
CLARENDON
WILLIAMSBURG
GEORGETOWN
CALHOUN
AIKEN
ORANGEBURG
BARNWELL
BAMBERG
ALLENDALE
DORCHESTER
BERKELEY
CHARLESTON
COLLETON
HAMPTON
JASPER
BEAUFORT
SCALE OF MILES
25
0
25
50
S C STATE HIGHWAY DEPT. - 1958

Figure 3-1.
NONATTAINMENT GEOGRAPHIC AREAS
OF THE STATE OF SOUTH CAROLINA

C. CLEAN AIR ACT AMENDMENT REQUIREMENTS FOR I/M PROGRAM

The passage of the 1977 Amendments to the Clean Air Act (CAAA) has brought about a number of new requirements for the control of air pollutant emissions from automobiles. Among the most important of these requirements is the idea that vehicles should maintain their lowest feasible emission levels throughout their lifetime. To attain this goal, the Act now specifies provisions for motor vehicle emission I/M programs. The purpose of this technical memorandum is to summarize the specifications of the CAAA with regard to I/M and forecast the implications of these specifications on the planning duties of the relevant environmental protection agencies.

1. CAAA Requirements

The CAAA include many specifications for the revision of State Implementation Plans (SIPs) and, in particular, call for the inclusion of transportation control measures which are necessary to attain and maintain National Ambient Air Quality Standards. Motor vehicle I/M programs have been shown to provide important emission reduction benefits and, hence, deserve attention as a potential transportation emission control measure for many areas throughout the country. This potential is recognized in the CAAA. Section 108 of the Act was amended to require the EPA to publish information regarding processes, procedures, and methods for implementing I/M programs. The EPA has fulfilled this charter through the publication of "Information Document on Automobile Emissions Inspection and Maintenance Programs" (Ref. 1).

More significant, perhaps, are the CAAA requirements for nonattainment areas and their inclusion in SIPs. Each state in which there are any nonattainment areas must submit a revised SIP by December 31, 1979 which provides for attainment of ambient air quality standards by December 31, 1982. In areas which demonstrate that the standards for oxidant or CO cannot be met by December 31, 1982, an extension to December 31, 1987 can be granted. Two of the many requirements for this extension are that an updated SIP revision must be submitted before July 1, 1982, and that a specific schedule for implementation of an I/M program be established. The EPA has also established the general requirements for I/M programs in a February 24, 1978 memorandum from the EPA Administrator to the Regional Administrators (reprinted in the Federal Register on May 19, 1978, 43 F.R. 21673).

In producing an I/M SIP revision, states must provide for:

1. An analysis of the benefits and costs of the program,
2. A public information effort,
3. A legislative proposal, and
4. A schedule for I/M implementation.

Before January 1, 1979, an SIP revision must be adopted by the state air pollution control board or agency head, as appropriate. As a part of the SIP revision submittal itself, there must be a commitment by the Governor to implement the I/M program according to the schedule submitted.

"Normally, adequate legal authority to implement a SIP revision must exist for a revision to be approved. Where a legislature has had adequate opportunity to adopt enabling legislation before January 1, 1979, the Regional Administrator should require certification that adequate legal authority exists for I/M implementation by January 1, 1979. However, for many states there will be insufficient opportunity to obtain adequate legal authority before their legislatures meet in early 1979. Therefore, a certification of legal authority for the implementation in these states must be made no later than June 30, 1979. An extension to July 1, 1980, is possible, but only when the state can demonstrate that a) there was insufficient opportunity to conduct necessary technical analyses and/or b) the legislature has had no opportunity to consider any necessary enabling legislation for inspection/maintenance between enactment of the 1977 Amendments to the Act and June 30, 1979. Certification of adequate legal authority, or other evidence that legal authority has been adopted, must be submitted to the EPA Regional Offices to be included in the SIP revision already submitted. Failure to submit evidence of legal authority by the appropriate deadline will constitute a failure to submit an essential element of the SIP, under Sections 110(a)(2)(I) and 176(a) of the Act.

Prior to the respective deadlines for initiating mandatory inspection and mandatory repair of failed vehicles, the state, local government, or regional agency should adopt whatever legally enforceable requirements are necessary to ensure that vehicles are not used unless they comply with the inspection/maintenance requirements. Written evidence of adoption of these requirements should be submitted to the EPA Regional Offices, to be included in the SIP revision already submitted by January 1, 1979" (see Appendix A).

"Implementation of I/M 'as expeditiously as practicable" shall be defined as implementation of mandatory repair for failed vehicles no later than 2-1/2 years after passage of needed legislation or certification of adequate legal authority for new centralized systems (State- or Contractor-operated) and 1-1/2 years after legislation or certification for decentralized systems (private garage-operated) or for centralized systems which are adding emission inspections to safety inspections. For the normal legislation deadline of June 30, 1979, new centralized programs must start by December 31, 1981, and all others must start by December 31, 1980. For the case of the latest possible legislation date, July 1, 1980, this means that a new centralized program must start by December 31, 1982, while all other programs must start by December 31, 1981. Where I/M can be implemented more expeditiously, it must be. Each state implementation schedule must be looked at individually to determine if it is as expeditious as practicable. Implementation dates ordered by courts, if earlier than these dates, take precedence" (see Appendix A).

The Emission Control System Performance Warranty contained in Section 207(b) of the Clean Air Act provides warranty coverage to motorists in areas having an I/M program. The Emission Performance Warranty, upon promulgation of regulation by the EPA, will require the automobile manufacturer to bear the cost of repair of any properly maintained and operated vehicle which fails an EPA established emissions test within 24 months or 24,000 miles, whichever occurs first, of the original sale to the ultimate purchaser. After this period, the warranty applies only to catalytic converters, thermal reactors, or other components installed on or in a vehicle for the sole or primary purpose of reducing vehicle emissions.

The CAAA extended the coverage of Section 203 of the Clean Air Act to prohibit the removal of, or tampering with, emission control equipment by independent auto repair operators. Civil penalties of $2,500 for such actions were also established.

2. Potential EPA Sanctions

There are sanctions for noncompliance with I/M requirements such that a state will lose its highway funds (except for transit-, safety-, or air quality-related transportation projects) if the Governor has not submitted an SIP revision by July 1, 1979, or that reasonable efforts toward submitting such a SIP are not being made (this also applies to the 1982 SIP revision). If state or local governments are not implementing an SIP, they cannot receive any grants under the Act. There is a requirement for Federal agencies not to take any action including making any grant that does not conform to an approved SIP, nor can any transportation planning agency give approval to anything which does not conform to the SIP. Priority must be given for programs with air quality-related transportation consequences to the implementation of SIPs necessary to achieve and maintain air quality standards.

D. I/M PROGRAM EFFECTIVENESS IN REDUCING HYDROCARBON AND CARBON MONOXIDE EMISSIONS FROM LIGHT-DUTY VEHICLES

Inspection and maintenance of light-duty vehicles has been shown to produce significant reductions in emissions of carbon monoxide (CO) and hydrocarbons (HC). Since mobile sources are usually the major contributors to CO and HC emissions in an urban area, the emission reductions produced by an I/M program can be translated into beneficial improvements in the region's air quality.

1. Emission Reduction Potential

The potential benefits which can result from an I/M program depend on a number of factors. The most important of these factors deals with I/M emission standards, or "cut points." The cut point is the level of emissions which distinguishes between those vehicles requiring emissions-related maintenance and those that do not. The cut points that are selected define a "stringency factor" which is a measure of the rigor of the program based on the estimated fraction of the vehicle population whose emissions would exceed cut points for either or both CO and HC. There are two basic concerns that constrain the selection of I/M emission standards. As mentioned previously, the I/M emission standards determine the emission reduction potential. As such, I/M standards or cut points should be set to achieve a desired emission reduction. On the other end, the cut point should be limited to a level that will be acceptable to both the general public and the repair industry. As experienced by other programs, negative public sentiments may result if an excessive volume of vehicles do not comply with I/M standards at first inspection. Further difficulties will arise if the total of the noncomplying vehicles exceed the available capacity of the repair industry. The necessary vehicle maintenance will be compromised under these conditions. Cut points must be set at a level where potential emission reduction benefits are maximized while impacts to the public are minimized. Detailed discussion of the stringency factor is given in Technical Memorandum E.

The air quality benefit from an I/M program is also dependent, in part, on the ability of the service industry to properly perform the repair work necessary to lower emissions. Depending on the level of service industry training, emissions could be reduced just to the levels which would pass the I/M test or well below them. Some savings in repair costs may also result from the training since the mechanics would be familiar with the problems and the best solutions.

The total emission reductions that result from the program are directly dependent on the number and types of vehicles inspected and the requirement that maintenance be performed. I/M programs are generally designed around automobiles and other light-duty vehicles; however, motorcycles and heavy-duty trucks can also be included to provide additional emission reductions. In some cases, it may be desirable not to require repairs on old cars when the repair work would cost a major percentage of the car's value.

Frequency of testing also can affect the emission benefit scenario. Most existing I/M programs require annual inspection. This frequency is justified on the basis that it minimizes costs and maximizes public acceptance while maintaining a reasonably high level of emission reduction. A semi-annual program would involve substantially higher program costs arising from the need for a greater number of inspection lanes, as compared to an annual inspection program. Semi-annual inspections may be justified for higher usage vehicles, such as taxis, however. A bi-annual program, while certainly providing some emission benefits, will lose some of the effectiveness of an annual program because cars are allowed to deteriorate to a higher level.

The definitive statement on potential emission reductions from an I/M program appears in the Code of Federal Regulation under the title of "Appendix N--Emissions Reductions Achievable Through Inspection, Maintenance and Retrofit of Light-Duty Vehicles" (see Appendix C).

2. Results of California Study

The California Air Resources Board (ARB) has conducted a number of study efforts to determine the emission-reduction potential of various I/M programs.

In May of 1976, results of these studies were published. The results of these studies indicated that those vehicles which were repaired under the idle I/M regime achieved immediate reductions of 38 percent in HC emissions and 33 percent in CO emission (see Tables 3-7 and 3-8). When these reductions are deteriorated over 1 year's time and distributed over the total vehicle population, the reductions are 9 percent HC and 8 percent CO.

These results generally agree with those obtained in other studies performed by and for the U.S. EPA and the ARB (see Table 3-9).

Table 3-9. COMPARISON OF EMISSIONS AND FUEL CONSUMPTIONS REDUCTIONS AND REPAIR COSTS WITH OTHER STUDIES

	IMMEDIATE REDUCTIONS - FAILED VEHICLES				ASSUMED
IDLE REGIME	HC	CO	NO_x	Fuel Consumption	FAILURE RATE
California Study (Ref. 2)	38%	33%	4.2%	3.8%	35%
Northrop (Ref. 3)	40%	37%	-13%	-	50%
EPA (Ref. 4)	42%	34%	5.0%	-	50%
Olson (Ref. 15)	38%	29%	-7.3%	3.0%	50%

A study made by the Northrop Corporation for the ARB in 1971 showed emissions reductions comparable to those in this study while using a 50 percent failure rate.

Table 3-7. HYDROCARBONS EMISSION REDUCTION IDLE REGIME (REF. 2)

MOTOR VEHICLE CLASSIFICATION	AVERAGE GM/MI
A. Without Deterioration:	
Pass *	4.02
Fail (Before Repair)**	7.21
Fail (After Repair)**	4.46
Immediate Reduction	2.75
% Decrease (Failed Vehicles)	38.19
Total Population	
Without MVIP	5.14
With MVIP	4.17
% Decrease	18.76
B. With Deterioration:	
Total Population	
Without MVIP	5.14
With MVIP	4.66
% Decrease	9.38

*Passed all Standards
**Failed one or more Standards

Table 3-8. CARBON MONOXIDE EMISSION REDUCTION IDLE REGIME (REF. 2)

MOTOR VEHICLE CLASSIFICATION	AVERAGE GM/MI
A. Without Deterioration:	
Pass *	41.69
Fail (Before Repair)**	65.42
Fail (After Repair)**	43.94
Immediate Reduction	21.48
% Decrease (Failed Vehicles)	32.84
Total Population	
Without MVIP	49.99
With MVIP	42.47
% Decrease	15.04
B. With Deterioration:	
Total Population	
Without MVIP	49.99
With MVIP	46.23
% Decrease	7.52

*Passed all Standards
**Failed one or more Standards

E. TESTING PROGRAM WITH A 30 TO 35 PERCENT FAILURE RATE

1. Introduction

This section addresses an emission testing program with a 30 to 35 percent failure rate. The percent failure rate is normally referred to as stringency factor.

A stringency factor is defined as "a measure of the rigor of a program based on the estimated fraction of the vehicle population whose emissions would exceed cut points for either or both CO and HC if there were no improvement in habits or maintenance quality to take place as a result of the program."

During the first year of program operation, the Appendix N credits allows certain percentage of reductions in HC and CO for stringency factors of from 0.10 to 0.50 as noted in Tables 3-10 and 3-11 (Ref. 6).

Table 3-10. FIRST YEAR PERCENT OF EMISSION REDUCTION OF HYDROCARBONS THROUGH I/M PROGRAMS

	FIRST YEAR						
	VEHICLE TYPE				ADDITIONAL BENEFITS		
					Mechanics Training		
STRINGENCY FACTOR	Technology I[a]	Technology II[b]	Motorcycles and LDT	HDT	Technology I	Technology II	Semi-annual Inspection
0.10	1	1	1		1	3	0.2
0.20	5	3	5	11.4	3	5	0.2
0.30	7	9	7	12.3	4	4	0.2
0.40	10	16	10	15.6	6	1	0.2
0.50	11	24	11	17.2	7	1	0.2

[a] Light-duty vehicles subjected to pre-1975 Federal emission standards.

[b] Vehicles subject to 1975 and later model-year Federal emission standards.

Table 3-11. FIRST YEAR PERCENT EMISSION REDUCTION OF CARBON MONOXIDE THROUGH I/M PROGRAMS

	FIRST YEAR						
	VEHICLE TYPE				ADDITIONAL BENEFITS		
					Mechanics Training		Semi-annual Inspection
STRINGENCY FACTOR	Technology I	Technology II	Motorcycles and LDT	HDT	Technology I	Technology II	
0.10	3	8	3		5	7	0.2
0.20	8	20	8	8.3	7	10	0.2
0.30	13	28	13	9.2	9	10	0.2
0.40	19	33	19	10.5	8	7	0.2
0.50	22	37	22	12.9	7	5	0.2

Subsequent years inspection credits and additional credits for mechanics training are set forth in Tables 3-12 and 3-13 (Ref. 2).

Table 3-12. SUBSEQUENT YEARS PROGRAM CREDITS FOR HC

			ADDITIONAL BENEFITS		
			Additive Credit HC (Percent)		
			Mechanics Training		
NUMBER OF INSPECTIONS	ADDITIVE CREDIT HC (PERCENT)	STRINGENCY FACTOR	Technology I Inspections 2	Technology I Inspections 3 or more	Technology II Inspections 2 or more
2	7	0.10	3	15	10
3	14	0.20	4	10	8
4	20	0.30	6	9	2
5	25	0.40	5	5	1
6	30	0.50	3	3	1
7	33				
8 or more	36				

Table 3-13. SUBSEQUENT YEARS PROGRAM CREDITS FOR CO

			ADDITIONAL BENEFITS		
			Additive Credit CO (Percent)		
			Mechanics Training		
			Technology I Inspections		Technology II Inspections
NUMBER OF INSPECTIONS	ADDITIVE CREDIT CO (PERCENT)	STRINGENCY FACTOR	2	3 or more	2 or more
2	8	0.10	3	13	4
3	15	0.20	8	15	2
4	19	0.30	5	9	1
5	23	0.40	5	5	3
6	27	0.50	2	2	1
7	30				
8 or more	35				

It is to be noted that Appendix N states that, for a viable program of benefit credits for a stringency factor at any level, it is necessary that the following activities must be initiated:

- Provisions for regular periodic inspection of all vehicles for which emissions reduction are claimed.

- Provisions for the establishment of inspection failure criteria consistent with the claimed reductions.

- Provisions to ensure that necessary vehicles receive the maintenance necessary to achieve compliance with the inspection standards. This might include sanctions against individual owners or repair facilities, retest of failed vehicles following maintenance, a certification program to ensure that repair facilities performing the required maintenance have the necessary equipment, parts and knowledge to perform the tasks satisfactorily, a program to train mechanics, and/or other measures.

- A program of enforcement to ensure that vehicles are not intentionally readjusted or modified subsequent to the I/M in such a way as would cause them to no longer comply with the inspection standards. This might include spot-checks of idle adjustments and/or a suitable type of physical tagging.

2. Emissions Percentages Appendix N Allowable for a 30 to 35 Percent Stringency Factor

The first year allowable minimum/maximum percentage reduction of emissions for 30 to 35 percent as developed from Tables 3-10, 3-11, 3-12, and 3-13 is presented in Tables 3-14 and 3-15 for I/M program implementation.

Table 3-14. FIRST YEAR PERCENT EMISSION REDUCTION OF HC FOR LDV I/M PROGRAM

STRINGENCY FACTOR	MINIMUM Technology I	MINIMUM Technology II	MAXIMUM Technology I	MAXIMUM Technology II
30	7	9	11.2	13.2
35	8.5	12.5	13.7	16.4

Table 3-15. FIRST YEAR PERCENT EMISSION REDUCTIONS OF CO FOR LDV I/M PROGRAM

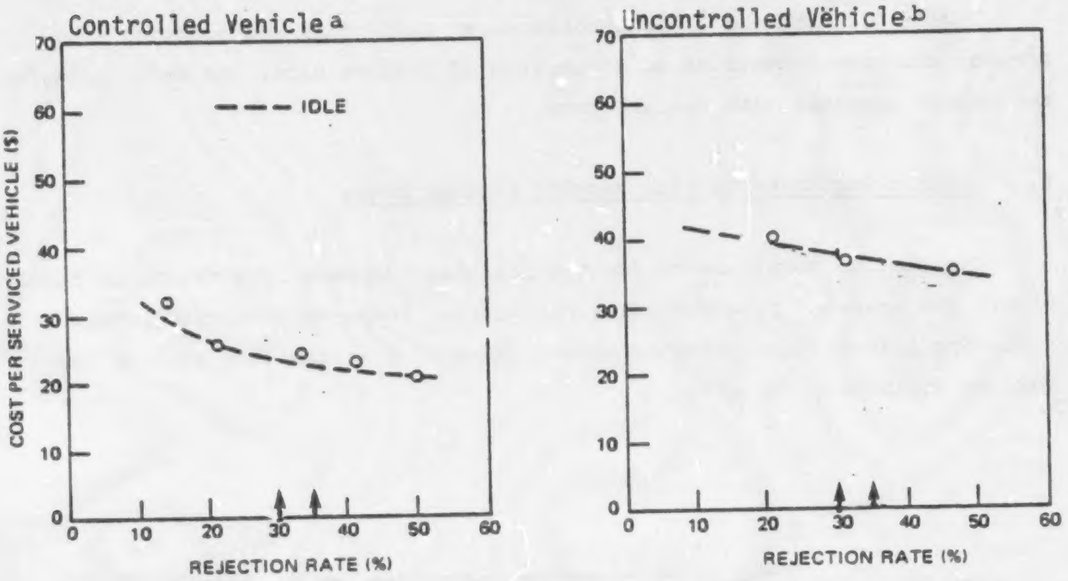
STRINGENCY FACTOR	MINIMUM Technology I	MINIMUM Technology II	MAXIMUM Technology I	MAXIMUM Technology II
30	13	28	22.2	38.2
35	16	30.5	24.7	39.2

Therefore, under an I/M program with a 30 to 35 percent failure rate, the first year emission reduction is between 7 to 16.4 percent for HC, and 13 to 39.2 percent for CO, depending upon the details of the test program. For the subsequential years, it increases in direct proportion to the number of years the inspections continued.

3. Repair Cost Per Service Vehicle Under Various Stringency Factors

The average cost of repair as noted in Figure 3-2 decreases with an increase of the stringency factor. This decrease in average cost is the result of the maintenance status of the vehicle due to the age of the vehicle. The older the vehicle the higher the cost of repairs.

CALIFORNIA AND MICHIGAN IDLE TEST DATA



COST PER SERVICED VEHICLE ($)

[a] Controlled Vehicle - vehicle manufactured after year 1968.

[b] Uncontrolled Vehicle - vehicle manufactured before year 1968.

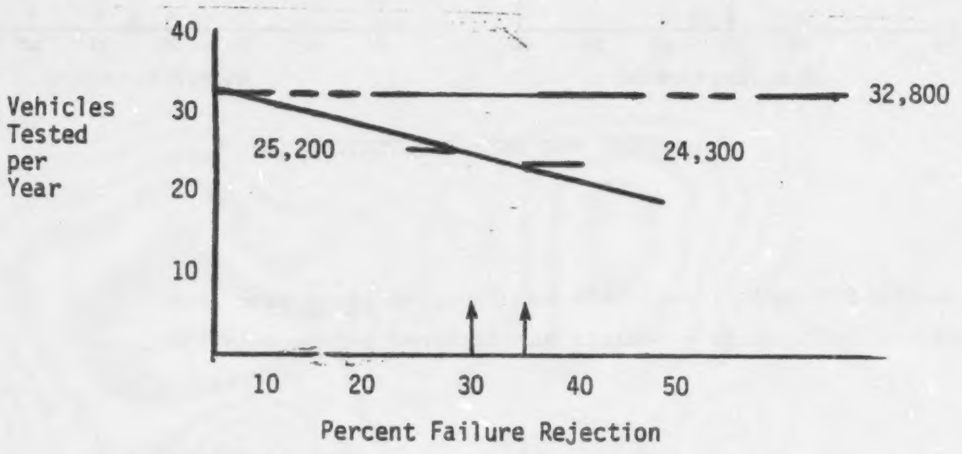
Figure 3-2. AVERAGE VEHICLE REPAIR COSTS (REF. 7)

4. Emission Reduction Versus Rejection Rate

Figure 3-3 from the Olson Laboratories' California and Michigan study, present emission reductions as a function of failure rate. As shown emission reductions increase with failure rate.

5. Station Requirements with Varying Failure Rates

The station requirements for testing will increase if a retest is required. Figure 3-4 presents flow sequences for various inspection/service levels. The following illustration presents output rates of a single-lane station for various stringency factors.



The above data is based upon a 3.5-minute throughput rate for an idle test, an 8-hour day, 40-hour week, 52 weeks out of the year, and with a 92 percent efficiency factor and the retest of those cars that were failed.

6. Idle Regime Standards for Emissions Surveillance

The standards for a failure rate of 35 percent of the vehicle population, based upon an idle test of more than 12,000 cars by the State of California, are presented in Table 3-16.

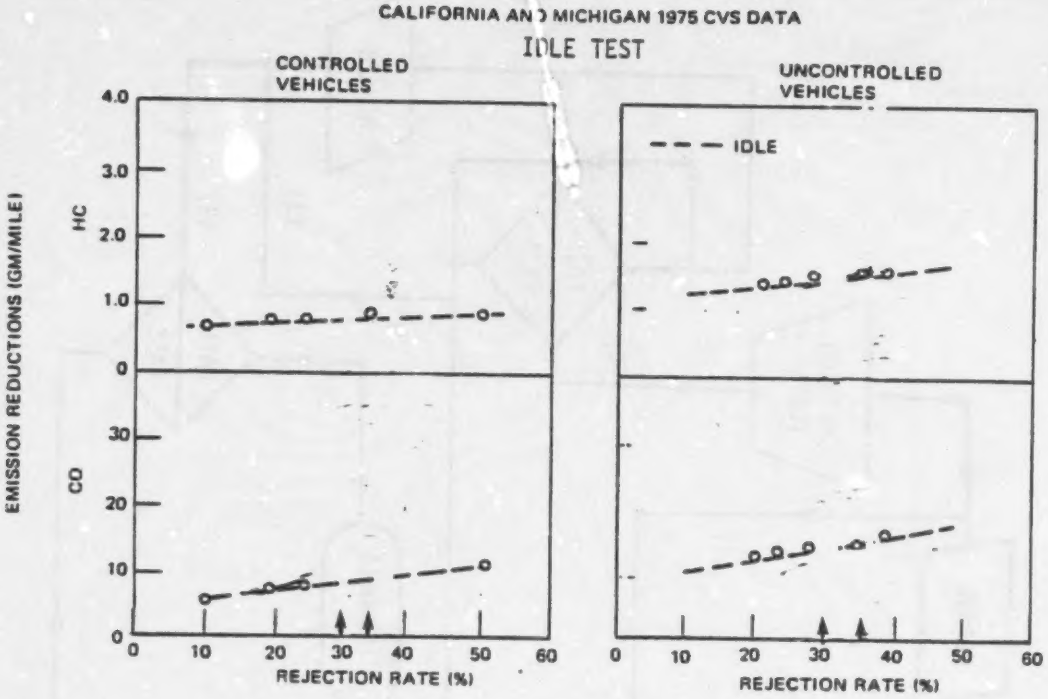


Figure 3-3.
EMISSION REDUCTIONS AS A FUNCTION OF REJECTION RATE

1. Test for fail/pass and repair no retest
2. Test for fail/pass, repair and retest
3. Test for fail/pass, repair, retest and repair
4. Test for fail/pass, repair, retest, repair, retest, and possible diagnosis

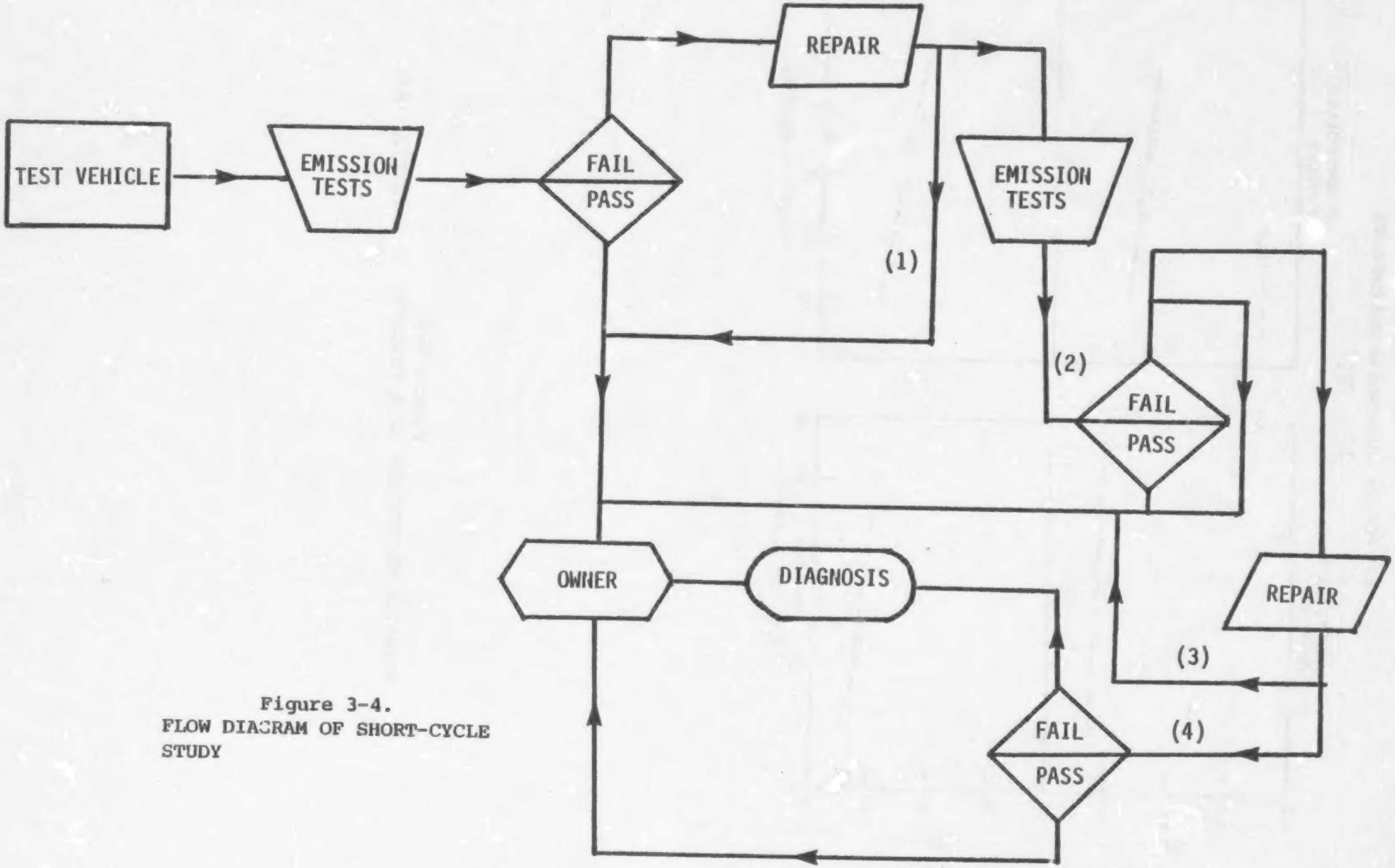

TEST VEHICLE
EMISSION TESTS
FAIL
PASS
REPAIR
(1)
EMISSION TESTS
(2)
FAIL
PASS
OWNER
DIAGNOSIS
REPAIR
(3)
FAIL
PASS
(4)

Figure 3-4.
FLOW DIAGRAM OF SHORT-CYCLE STUDY

Table 3-16. IDLE REGIME STANDARDS FOR 35 PERCENT FAILURE REJECTION

MODEL YEAR	TYPE CONTROL	MORE THAN 4 CYLINDERS		4 CYLINDERS OR LESS	
		HC (gm/mi)	CO (gm/mi)	HC (gm/mi)	CO (gm/mi)
1955-1965 (domestic) 1955-1967 (import)	None	1,200	8.0	1,800	8.0
1966-1970 (domestic) 1968-1970 (import)	AI[a]	350	4.5	350	3.0
1966-1970 (domestic) 1968-1970 (import)	Other	500	6.0	600	6.0
1971 and later	AI	200	3.0	275	3.0
1971 and later	Other	350	4.5	400	5.0

[a] AI = Air injection.

Source: Reference 1.

F. ADMINISTRATIVE PROGRAM OPTIONS

This section presents background documentation on I/M administrative alternatives proposed by the South Carolina DHPT. These alternatives considered are:

- Government-operated
- Contractor-operated
- Private garage-operated

Much of the following information was compiled from past and current I/M studies. The intent was to provide South Carolina with adequate decision-makers necessary to evaluate the proposed alternatives.

This section is organized into four parts:

- Administrative Options Defined
- General Background Information
- Qualitative Comparisons
- Functional Comparisons

The first two parts carefully define the administrative options and provide in-depth analysis of each alternative using past I/M studies. The remaining two parts compare each option by identifying specific responsibilities, roles, and functional relationships.

1. Administrative Options Defined

The three alternative administrative options characterizes the operational format of the inspection phase of an I/M program. In each case, private service garages and dealerships comprising the automobile repair industry will participate in the maintenance phase. Conceptionally, the selection of a specific configuration should not have an impact on I/M program emissions effectiveness. However, the administrative option does have substantial effects on capital and operational costing expenditures, quality assurance, enforcement, etc.

a. Government-Operated

Under a government-operated program, a designated agency at either the state or municiple levels would assume complete managerial and operational control of a centralized system of publicly owned facilities.

b. Contractor-Operated

A contractor-operated program is an arrangement whereby a corporation, selected through a competitive bid process, assumes operational responsibility for emission inspection at centralized test facilities. Administrative control is still under the responsibility of a public authority.

c. Private Garage-Operated

Under a private garage-operated program, a public authority would certify and license selected private establishments (e.g.; service garages, dealerships, and independents) to perform emission and safety inspections. This would provide a network of decentralized inspection and repair facilities.

2. Background Information on Current I/M Programs

Available background information on I/M programs throughout the country are summarized in Table 3-17. Each I/M program is classified as either state-, contractor-, or private garage-operated. For each program type, detailed information such as responsible agency, number of vehicles serviced, stringency factors, emission test, facility site, and estimated costing data (i.e.; capital, operation, inspection cost) are provided under appropriate headings.

Govenment I/M programs can be further subdivided into either state or municipally-owned/operated programs. New Jersey operates a state program that annually idle tests 3.9 million light-duty vehicles (LDVs) at 38 station (62 lane capacity). This requires $2.5 and $1.3 million dollars in capital and operating costs, respectively.

Table 3-17.
EXISTING I/M PROGRAM SUMMARY

PROGRAM TYPE	STATE	ADMINISTRATIVE AGENCY	VEHICLE POP (Millions)	TEST MODE AND STRINGENCY[a]		STATION STATUS			COST (Millions $ Yr)		INSPECTION FEE
				L.D.V.	H.D.V.	#Lanes	#Sta.	Mobile	Capital[b]	Operating[b]	
I. GOVERNMENT A. State	New Jersey	DMV - EPA	3.9 LDVs	Idle 23%	NA	62	38	1	$2.50 (1972) +	$1.33	$3.50 including safety
	Oregon[c] Portland	Dept. of Environ. Qual.	0.55 LDVs (biennial)	Idle 40%	NA	14	7	1	$0.38 Leased facil. (1975)	$2.22	$5
B. Municipal	Ohio, Cincinnati	Cincinnati APCD[d]	0.2 LDVs	Idle 30%	NA	4	1	None	$0.013 safety facil.	$0.13 for	$3.75 including safety
	Illinois, Chicago	Chicago Dept. Env. Control	1.1 LDVs	Idle 30-35%	NA	10	5	6	$2.0 (1973)	$1.45 (1977)	Free[e,f]
II. CONTRACTOR	Arizona,[g] Maricopa and Pima counties	Ariz. Dept./ Health Ser.	1.1 cars, trucks, and motorcycles	Idle[h] 30%	EPA City	36	12	1	$10.5	$4.0	$5
III. PRIVATE GARAGE	Nevada (Clark Co. only)	Dept. Motor Vehicles and Dept. Human Resources	0.20 LDVs	Idle	NA	218 Licensed Private Stations			$0.17 (1974)	$0.43 approx. (1974)	$10.00-$33.00 (including adjustments)
	Rhode Island	Dept. of Transportation	0.5 LDVs	Idle 30%	NA	923 Private Garages + 1 State-Operated challenge lane			$1.00 (1977)	Part of Capital cost 1st year	$4

[a] Percent of vehicle failing to meet established standards.

[b] Cost data defined per particular year. To upgrade costs to present year multiply by appropriate inflation factor.

[c] State of Oregon, Oregon Environmental Quality Commission - "Report to the Oregon Legislature on the Motor Vehicle Emission Testing Program," January 14, 1977.

[d] Air Pollution Control Department.

[e] Included as part of the registration fee.

[f] Chicago's program costs are covered by a city sticker fee.

Definitions: DMV - Department of Motor Vehicles.
LDV - Light-Duty Vehicle (GVW <8501 lb.).
HDV - Heavy-Duty Vehicle (GVW >8500 lb.).

[g] State of Arizona, Bureau of Vehicular Emissions Inspections - "Tune-up for Less Emission - It's Working Arizona Vehicular Emissions Inspection Program Operations", 1977.

[h] Loaded test with only idle fail/pass standards.

Municipally-operated programs are found in Ohio (Cincinnati), Oregon (Portland), and Illinois (Chicago). These programs annually inspect 0.2 to 1.1 million vehicles. Ohio has only one station, but intends to expand the program later. Illinois currently operate five 2-lane capacity test stations. In addition, Illinois operates 6 mobile test units. Illinois expenditures are $20 million for capital costs and $1.45 million annaul operating expenses.

The only contractor-owned/operated program is located in Arizona (Maricopa and Pima Counties). The 12 test stations annually process an estimated 1.1 million cars, trucks, and motorcycles using 30 percent stringency factor with idle test requirements. Capital cost expenditures are estimated al0.5 $9 million with annual operating costs approaching $4.0 million.

After a 2-year (Phase I) feasibility pilot program (Refs. 9 and 10); on March 1, 1979 California implemented a change of ownership program operated by a private contractor (Phase II). This contractor-administered program operates 78 testing facilities at an estimated $12 million in capital outlay, and $22 million (1978 dollars) in capital costs (Ref. 1). The inspection fee is $11.00.

At present, Nevada and Rhode Island are the only states that have private garage-operated I/M programs. Rhode Island has an extensive program, testing 0.5 million vehicles at 923 certified private garages. The Nevada program is comparatively smaller, licensing only 218 garages to test 200,000 vehicles. As expected, the capital cost expenditures for Rhode Island is quite large compared to Nevada. Unexpectedly, the cost to the motorist is quite high for Nevada ($10.00 to $33.00) compared to Rhode Island ($4.00). However, the Nevada program does have vehicle adjustment included on the test requirements.

For each I/M program type, typical problems encountered during implementation and their subsequent solutions are shown in Table 3-18. Additional information includes representative achievements for each state I/M program.

Table 3-18.
TYPICAL I/M PROBLEMS, SOLUTIONS AND ACHIEVEMENTS

PROGRAM TYPE	STATE & RESPONSIBLE AGENCY	PROBLEMS	SOLUTIONS	ACHIEVEMENTS
I. GOVERNMENT-OPERATED				
A. State-Operated	California	.(Pilot Program) Minimal Problems		.Public Reaction Excellent .Unique Combination of Exhaust Analysis, Engine Monitoring, and Computer Technology .Diagnostic Testing
	New Jersey	.2-Year Exemption for New Cars .Lack Operating Capital Capacity Improvements Cannot be Made .DMV Resistant to Increased Refailure Rate Expected in Phase III standards (23%) .Refailure Rate is 25%	.Legislation Pending .Funding Has Increased $330,000 .No Position Change .Refailure Rate Now 11%	.Nation's Longest On-Going I/M Program .4,700 Garages Now Utilizing Exhaust Analyzers .Private Garage Reinspection Program
	Oregon Portland	.Biennial Inspection Lowers Program Effectiveness, Created Cash Flow and Personnel Problems .Tampering	.Inspection Period Will be Shortened .Trying to Implement An Annual Inspection Cycle, Requires Legislation Action	.Estimates Reduction of HC is 14% and CO 7% .Private Garage Acceptance is Increasing
B. Municipal-Operated	Ohio Cincinnati	.Low Throughput .Inadequate Enforcement .No Phase-In Period and No P.R. Program .Mechanics Inadequately Trained	.Improved Enforcement Led to Increased Throughput .P.R. Program Needed .Mechanic Training Program	.Demonstrated Short Lead Time in Adding I/M Program to Safety Program
	Illinois Chicago	.Less Than 20% of Registered Vehicles Have Been Inspected	.Increased Enforcement Policies .Favor Mandatory Inspection with Three Conditions: 1. Fed. Govt. and Auto Manufacturer's Concurrence On Warrantee Program 2. Auto Manufacturer's Compliance With Existing Statutory Emission Standards 3. I/M Implementation Over Regional Area	.Communication Channels Established with Auto Manufacturers Regarding High Emission Levels of Late Model Vehicles .Nation's First Fully Automated Inspection Program

Table 3-18.

TYPICAL I/M PROBLEMS, SOLUTIONS AND ACHIEVEMENTS (Continued)

PROGRAM TYPE	STATE & RESPONSIBLE AGENCY	PROBLEMS	SOLUTIONS	ACHIEVEMENTS
II. CONTRACTOR-OPERATED	Arizona Maricopa and Pima Counties	.Initial Adverse Public Reaction .Queuing Problems .Tampering .Inadequate Inspector Training	.Expected to Disappear With Increased Efficiency and Better Public Awareness .Needs Contractor Monitoring	.Nation's First Contractor-Operated Program
III. PRIVATE GARAGE-OPERATED	Nevada Clark County	.Minimal		.DMV Control of Licensing of Stations and Inspectors .Minimal Cost
	Rhode Island	.Inadequate Training of Garage Mechanics .Some Garages Violated Regulations	.On-Going Mechanic Training Program .Constant Monitoring Needed	.Program Initiated by Governor and Rhode Island DOT With Backing From Executive and Legislative Branches .State-Run Inspection Facility Used as Reference Station

3. Qualitative Comparison of Administrative Programs

Table 3-19 presents qualitative information for the state, contractor, and private garage systems as a function of various cost categories and related considerations. The program cost implications in terms of state financial involvement were also evaluated. In addition, major operation program responsibilities were identified for each administrative option.

4. Functional Comparisons

The implementation of comprehensive emission control program requires the cooperation of several governmental agencies and departments (Figure 3-5). These agencies and departments provide support services in three general areas -legal, environmental, and enforcement. For example, legal services provided by the joint cooperation of the Consumer Affair's Office and Attorney General's Office include a complaint information and referral system, an ongoing public relations program, and legal redress mechanisms. Environmental services could be provided by the Environmental Protection Division consisting of an on-line computer analyses of emissions test data. Finally, enforcement services could include direct computer access to the Department of Motor Vehicles Registration files, personnel training facilities and capabilities, and safety/spot check programs.

These support activities could be coordinated by a state administrated Motor Vehicle Emissions Control Office (MVECO). Additional responsibilities should include quality and operational controls of the day-to-day business of the various inspection test centers.

The three alternative administrative approaches (state, contractor, and private garage) differ in the operational format of the total I/M framework. For instance, a contractor-operated program (Figure 3-6) is responsible for their own internal quality control program. The state would provide independent checks on quality assurance in the form of correlation vehicles and referral stations. In addition to correlation vehicles, referrals stations, etc., private-garage operations (Figure 3-6) would require a certification program for both mechanics and repair facilities (Figure 3-5).

Table 3-19.
QUALITATIVE COMPARISON OF ADMINISTRATIVE PROGRAM OPTIONS

COST CATEGORIES AND CONSIDERATIONS	STATE-OPERATED	CONTRACTOR-OPERATED	PRIVATE GARAGE-OPERATED
Instrumentation and Technology	Design, requirements analysis, and specification development is required.	Will have expertise in these areas.	Will have some basic expertise, but will need to be expanded.
Site Acquisition	Initial capital cost required.	Low capital cost to state, deferred to operational charge.	Capital invested already.
Facility Construction and Acceptance	Capital investment required, local government approval to meet zoning laws.	Contractor agency will require building inspection approval by the State and local government.	Facilities available.
Equipment Acquisition and Installation	Volume discount.	Moderate cost volume discount.	Each participating garage will have to purchase equipment that it does not already have.
Maintenance and Support, Inspection-Oriented Equipment	Preventive maintenance done by facility personnel; major corrective maintenance done either by a single technical department or contracted outside service; moderate cost to State.	Minor corrective maintenance done by facility personnel; major corrective maintenance done by contracted service; no cost to State.	Preventive and minor corrective maintenance done by facility personnel; major corrective maintenance probably done by contracted service; no cost to State.
Quality Control and Support Activities	Periodic confidence testing and calibration functions; minor repairs of supporting equipments done by facility personnel; major repairs done by single department or contracted; moderate cost to State.	Periodic confidence testing and calibration of minimum number of stations by state. Data processing by state.	Performed by State agency. Numerous stations to be checked. Data processing input from card decks.

Table 3-19.
QUALITATIVE COMPARISON OF ADMINISTRATIVE PROGRAM OPTIONS (Continued)

COST CATEGORIES AND CONSIDERATIONS	STATE-OPERATED	CONTRACTOR-OPERATED	PRIVATE GARAGE-OPERATED
Program Management and Functions	Maintain records, schedule vehicles, collect fees, review emission results, update standards and documentation, determine future requirements, evaluate newer equipments, determine budgetary requirements, and other program management functions; may involve many separate State agencies, new and/or existing; moderate cost to State.	Similar management functions to State operated program, but with State agency that oversees contractor administration; moderate cost to State.	Requires State to audit all records on regular basis; high cost to State.
Program Management and Administration Surveillance Program	Periodic certification of existing facilities; qualification/certification of new facilities; moderate cost to State.	Periodic certification of contractor facilities by State inspection team; moderate cost to State.	Private-operated facilities certified by State personnel; high cost to State.
Initial Personnel Training and Indoctrination	Single department responsibility; uniform training policy, course content; minimum quantity of trained instructors, equipment, buildings; moderate cost to State.	Require single department responsible for training, etc.; minimal cost to the State.	Possibly many diverse training policies, course contents, equipment, facilities, instructors; requires guidance from State agency on requirements; minimal cost to State.
State Qualification and Certification	Single departmental responsibility; uniform qualification and certification policies; minimum quantity of technical and administrative personnel; moderate cost to State.	State responsibility to supervise initial operation of program; moderate cost to State.	Mandatory that State qualify and certify stations; high cost to State.

Table 3-19.

QUALITATIVE COMPARISON OF ADMINISTRATIVE PROGRAM OPTIONS (Continued)

COST CATEGORIES AND CONSIDERATIONS	STATE-OPERATED	CONTRACTOR-OPERATED	PRIVATE GARAGE-OPERATED
Vehicle Scheduling	Single departmental responsibility.	Mandatory that State be responsible.	Mandatory that State be responsible.
Facility Inspection Personnel Salaries, wages, etc.	Technical rating dependent on test regime; cost proportional to technical requirements; salaries and benefits must be competitive to attract higher-rated personnel; high cost to State.	Technical rating dependent on test regime requirements.	Technical rating depends on test regime; cost proportional to technical rating.
Quality Assurance	Responsible for complete audit of all records; complete data analysis; adjusting confidence limits; moderate cost to State.	Calibration records frequently audited by State personnel; State responsible for complete data analyses; moderate cost to State.	Difficult to implement because of instrument differences, diversified personnel; high cost to State.
Personnel Services	Strict use of civil service personnel.	May use part-time employees during periods of high-use.	May use part-time employees.
Hiring/Firing Practices	Requires lengthy review periods before workers are hired or fired.	Immediate - based on need and personnel personnel performance.	Immediate - based on need and personnel performance.
Public Attitude	Greater public acceptance and credibility of program objectives.	Unknown.	Low - distrust of private business operations.
Industry Attitude	Low - industry may perceive this as another state program and fail to see program objectives.	Unknown.	Low - industry has seen other I/M programs has ineffective and costly to vehicle.

Table 3-19.
QUALITATIVE COMPARISON OF ADMINISTRATIVE PROGRAM OPTIONS (Continued)

COST CATEGORIES AND CONSIDERATIONS	STATE-OPERATED	CONTRACTOR-OPERATED	PRIVATE GARAGE-OPERATED
Federal Legislation	Requires revision of SIP for centralized systems.	Requires revisions for for centralized systems.	Requires revisions to SIP for decentralized systems - additional Federal provision required.
State Legislation	Must provide provisions that include regular periodic inspections, maintenance and retest, quality control, and emissions reduction.	Provide provisions for SIP revisions that inspections, maintenance and retest, quality control and emissions reduction.	Requires additional provisions for licensing of inspection facilities, must met program requirements (e.g., instruments, provide personnel with adequate training).
State Liability	State assumes complete financial and operational liability for I/M program.	Contractor assumes financial and operational liability. State oversees program management and operations.	Private contractor assumes financial responsibility. State oversees program management of quality control and test data analysis.

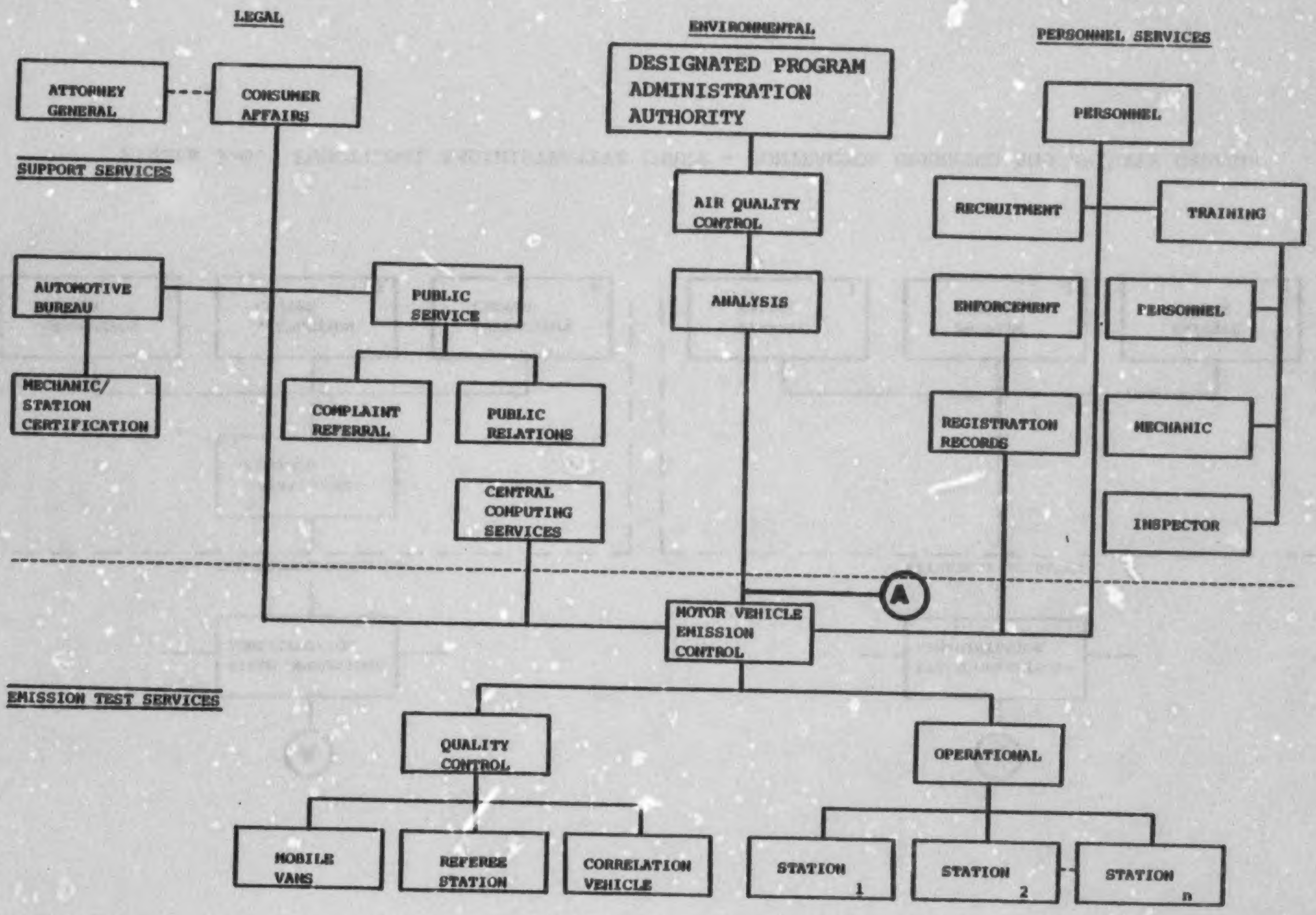

LEGAL
ENVIRONMENTAL
PERSONNEL SERVICES
ATTORNEY GENERAL
CONSUMER AFFAIRS
DESIGNATED PROGRAM ADMINISTRATION AUTHORITY
PERSONNEL
SUPPORT SERVICES
AIR QUALITY CONTROL
RECRUITMENT
TRAINING
AUTOMOTIVE BUREAU
PUBLIC SERVICE
ANALYSIS
ENFORCEMENT
PERSONNEL
MECHANIC/ STATION CERTIFICATION
COMPLAINT REFERRAL
PUBLIC RELATIONS
REGISTRATION RECORDS
MECHANIC
CENTRAL COMPUTING SERVICES
INSPECTOR
A
MOTOR VEHICLE EMISSION CONTROL
EMISSION TEST SERVICES
QUALITY CONTROL
OPERATIONAL
MOBILE VANS
REFEREE STATION
CORRELATION VEHICLE
STATION 1
STATION 2
STATION n

Figure 3-5. Functional Administrative Chart

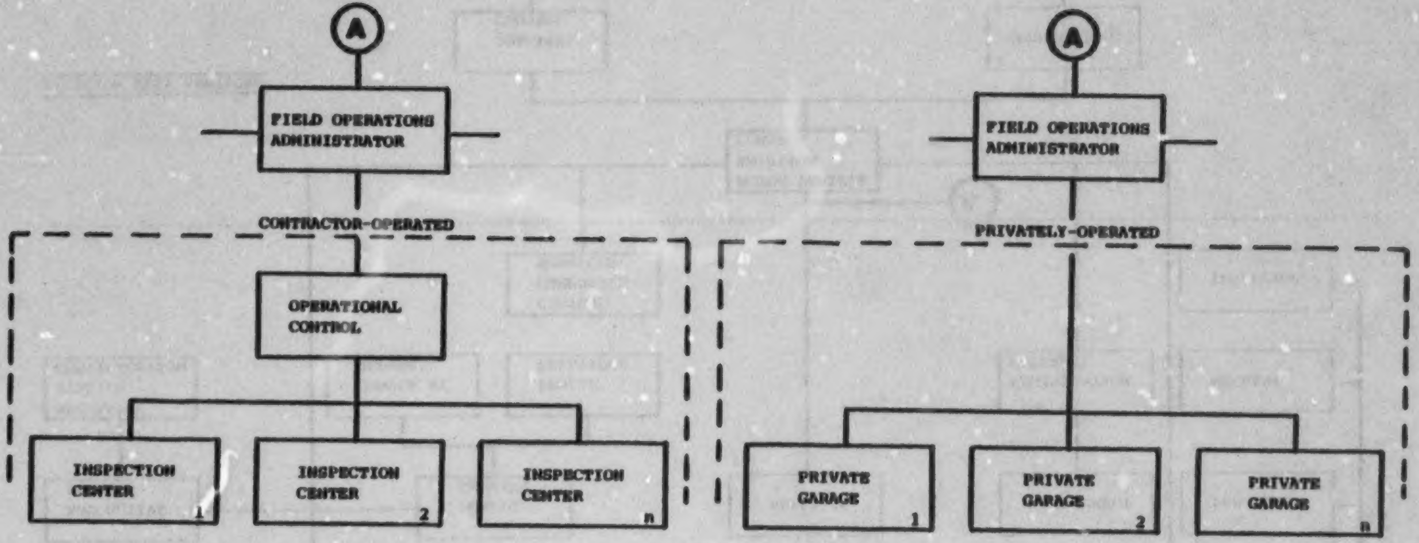

A
FIELD OPERATIONS ADMINISTRATOR
CONTRACTOR-OPERATED
OPERATIONAL CONTROL
INSPECTION CENTER 1
INSPECTION CENTER 2
INSPECTION CENTER n
A
FIELD OPERATIONS ADMINISTRATOR
PRIVATELY-OPERATED
PRIVATE GARAGE 1
PRIVATE GARAGE 2
PRIVATE GARAGE n

Figure 3-6. FUNCTIONAL AMDINISTRATIVE CHART - CONTRACTOR OPERATED AND PRIVATE GARAGE

This functional outline, rather than a strict organizational plan, is intended as a guide for South Carolina. The above mentioned agencies and/or departments are typical of most state organizations, however, they may be replaced with others more suitable to the particular requirements of South Carolina.

G. IDLE-MODE TEST

The idle-mode test is a measurement of the exhaust emissions with the vehicle in a neutral gear and the engine at idle. Often, hydrocarbon (HC) and carbon monoxide (CO) levels are recorded at both a normal and high idle speed. The test at the normal idle speed is taken at the manufacturer's recommended idle, measured in revolutions per minute (rpm), and then the engine speed is increased to 2,500 rpm for the high idle speed test.

The overall test procedure includes the collection of vehicle identification data (year, make, model, license number, vehicle identification number, etc.), visual inspection of the exhaust system and emission control devices, the exhaust emission test and recording of the test data.

The idle inspection and repair flow diagram, Figure 3-7, illustrates the following sequence of events. Based on the exhaust emission test data a pass/fail decision is made and discussed with the vehicle owner. Passed vehicles are certified, and if indicated by the emission data, impending malfunctions are discussed with the owner. The vehicle is then released. Failed vehicles are diagnosed for probable cause of failure and released to the owner for repair. After the repair(s) is performed, the vehicle is returned to the facility and retested. The idle inspection and repair flow diagram, Figure 9, illustrates this sequence of events.

The general characteristics of idle mode testing are as follows:

- Simple test procedure that requires minimum training for inspectors.
- Carburetor adjustments can be made during test.
- Diagnosis of some engine maladjustments and malfunctions.
- Can be duplicated by either public or private test systems.
- Requires minimal test time and equipment.
- Malfunctions that occur under loaded conditions may not be detected.
- NO_x testing cannot be performed.

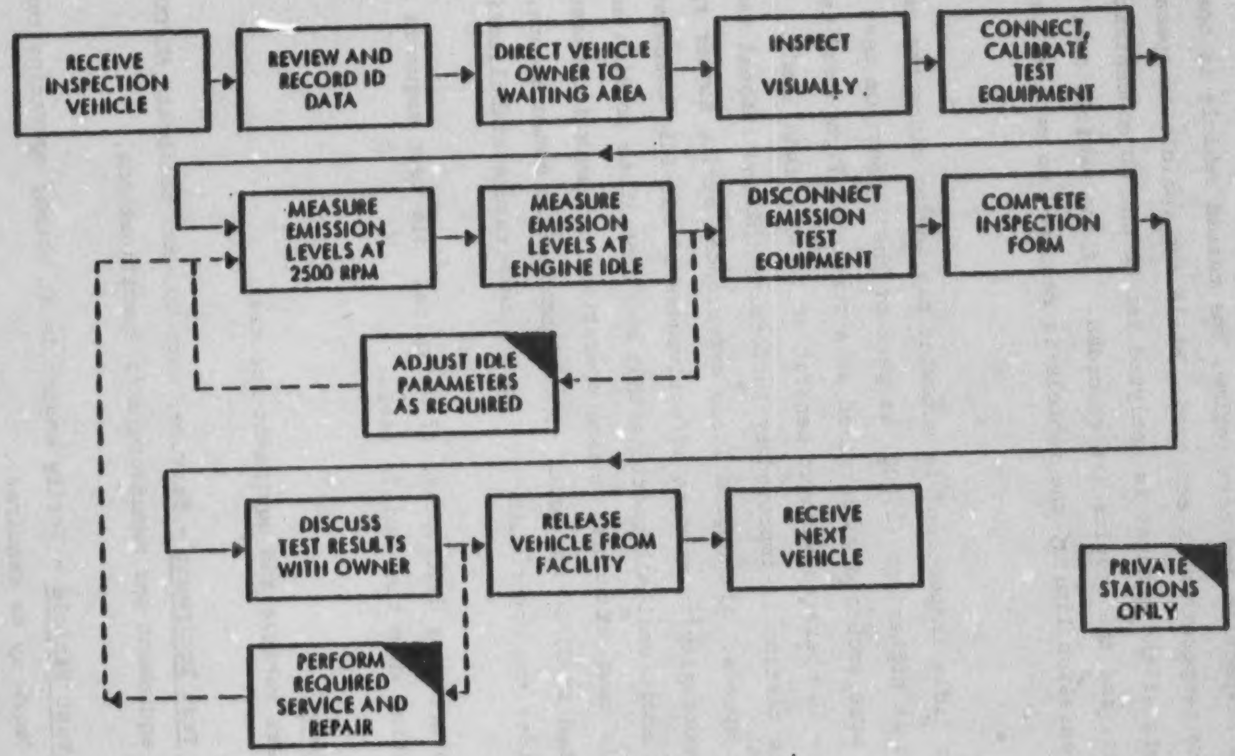

RECEIVE INSPECTION VEHICLE
REVIEW AND RECORD ID DATA
DIRECT VEHICLE OWNER TO WAITING AREA
INSPECT VISUALLY.
CONNECT, CALIBRATE TEST EQUIPMENT
MEASURE EMISSION LEVELS AT 2500 RPM
MEASURE EMISSION LEVELS AT ENGINE IDLE
DISCONNECT EMISSION TEST EQUIPMENT
COMPLETE INSPECTION FORM
ADJUST IDLE PARAMETERS AS REQUIRED
DISCUSS TEST RESULTS WITH OWNER
RELEASE VEHICLE FROM FACILITY
RECEIVE NEXT VEHICLE
PERFORM REQUIRED SERVICE AND REPAIR
PRIVATE STATIONS ONLY

Figure 3-7.
IDLE INSPECTION AND REPAIR FUNCTIONS

Idle Inspection Test Mode

In this inspection and test regime, the tested vehicle is operated until proper engine temperature is achieved. While the vehicle is operating at idle, a sample of the exhaust is analyzed for HC and CO concentration in the gas analyzers, and the results are recorded. If the vehicle does not pass the established emission limits, the vehicle is required to receive corrective action.

The term "idle inspection" is somewhat misleading since the vehicle is also operated at higher rpm (2,500) as part of the inspection test cycle. The test mode is more accurately described as a static or light-load test, as the vehicle engine is operated without benefit of vehicle road loads. The sensitivity of idle testing is improved by performing this additional testing at higher engine speeds. The engine loads experienced during higher rpm operations provide an opportunity to measure effectiveness of off-idle carburetor circuits and to detect additional malfunctions that may contribute to high emissions. During the idle test procedure, engine operations and emission measurements are accomplished at 2,500 rpm prior to performing idle measurements. This sequence provides the opportunity for engine temperature stabilization.

The following is a description of a typical idle test sequence and diagnostic information when the vehicle fails:

- Pre-Test
  Prepare vehicle and equipment for test.

  - Test Equipment - Service, warm up, and calibrate HC/CO test equipment per manufacturer's specifications.

  - Test Vehicle - Verify engine is at normal operating temperature (warm up as required).

  - Hook-Up - Insert probe in exhaust pipe (driver side if dual exhaust), hook up tachometer per manufacturer's instruction.

- Test

  Perform HC/CO and rpm measurements and compare to idle test standards.

  - 2,500 rpm - Operate engine in neutral at 2,500 rpm, record HC/CO.

  - Idle rpm - Operate engine at idle rpm (in drive if automatic transmission), record measurements.

- Post Test

  Make pass/fail decision and discuss results with vehicle owner.

  - Passed Vehicle - Certify and release.

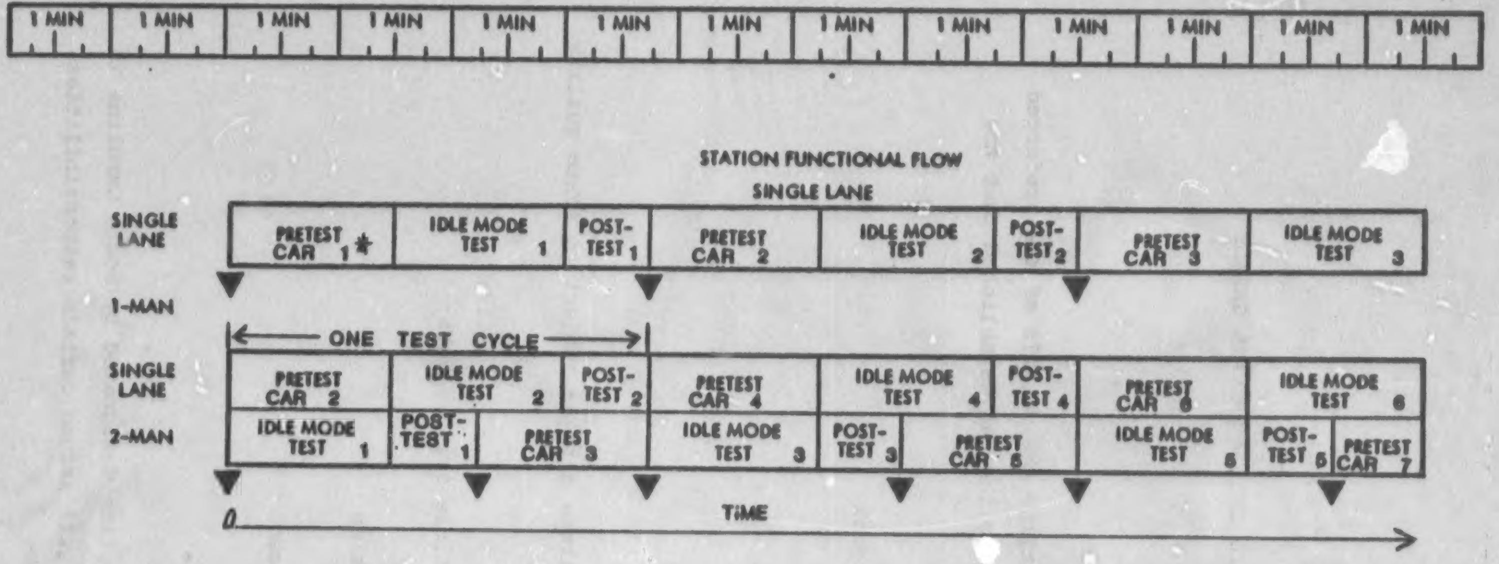
  - Failed Vehicle - Diagnose for probable cause of failure and instruct vehicle owner in retest procedure.

Idle HC/CO failure/malfunction truth table can be used as a guide to identifying failures (see Table 3-20). A functional flow diagram for the idle test regime is shown in Figure 3-8.

Table 3-20.

MALFUNCTION TRUTH TABLE FOR IDLE TESTING

MALFUNCTION	HC		CO		ROUGH IDLE
	High	Very High	High	Very High	
PCV Valve Diruty/ Restricted			X		X
Air Cleaner Dirty/ Restircted			X	X	
Choke Stuck Partially Closed				X	
Carburetor Idle Circuit Malfunction	X		X		X
Intake Manifold Leak	X	X			X
Ignition Timing Advanced	X				
Leaky Exhaust Valves	X	X			X
Ignition System Misfire	X	X			X


1 MIN
STATION FUNCTIONAL FLOW
SINGLE LANE
SINGLE LANE
1-MAN
PRETEST CAR 1 *
IDLE MODE TEST 1
POST-TEST 1
PRETEST CAR 2
IDLE MODE TEST 2
POST-TEST 2
PRETEST CAR 3
IDLE MODE TEST 3
ONE TEST CYCLE
SINGLE LANE
2-MAN
PRETEST CAR 2
IDLE MODE TEST 2
POST-TEST 2
PRETEST CAR 4
IDLE MODE TEST 4
POST-TEST 4
PRETEST CAR 6
IDLE MODE TEST 6
IDLE MODE TEST 1
POST-TEST 1
PRETEST CAR 3
IDLE MODE TEST 3
POST-TEST 3
PRETEST CAR 5
IDLE MODE TEST 5
POST-TEST 5
PRETEST CAR 7
0
TIME

STATION FUNCTION FLOW SUMMARY TABLE

	SINGLE LANE		DOUBLE LANE	
TEST CREW SIZE	1	2	3	4
VEHICLES PER HOUR	17	34	51	68
AVG TIME PER VEHICLE (MIN)	3.75	1.8	1.25	.9
SLACK TIME PER HOUR	0	0	0	0

PRETEST TIME	1.5
TEST TIME	1.5
POST-TEST TIME (PASS)	.25
POST-TEST TIME (FAIL)	1.25
POST-TEST TIME (AVERAGE)	.75

Figure 3-8.
IDLE TEST STATION FUNCTIONAL FLOW

* NUMERICALS INDICATE SEQUENTIAL ORDER OF VEHICLE TESTING.

▼ INDICATES VEHICLE OUTPUT.

SCI SYSTEMS CONTROL, INC.
ENVIRONMENTAL ENGINEERING DIVISION

Section 4

DETAILED ANALYSIS OF PREFERRED OPTION/PRIVATE GARAGE

A. PROGRAM DESCRIPTION

The purpose of this section is to outline the details of the preferred I/M program option. The State of South Carolina has established that the following scenario will be implemented:

- Program to start in 1982, as a goal
- Idle-mode testing
- Four-county area
    - Berkeley
    - Charleston
    - Richland
    - Lexington
- Tests to be administered by private garages subject to state quality control
- Annual spection
- No control of out of county vehicle trip effects
- Vehicle categories - LDV, LDT
- Enforcement - vehicle registration
- Emissions checked HC, and CO
- Stringency factor 30 to 35 percent.

1. Program Administration

The preferred test administrative option designated by South Carolina is the private garage. However, the State will assume certain responsibilities.

For instance, referring to the organizational chart presented in Figure 3-5, Section 3.F, the State would maintain a Motor Vehicle Emission Control Office. This office would be responsible for coordinating efforts in public relations, quality assurance, facility certification and consumer protection investigations. A state testing center would be maintained by the State to provide a capability for special complaint and problem resolutions.

a. Private-Garage Operation

The preferred option approach may require State-operated regional offices, but all inspections would be performed by private garages. Each private garage operator would be responsible for submitting necessary data to the State of South Carolina for data processing and statistical report generation.

2. Test Mode

An idle test mode has been designated as the preferred test mode option by the State of South Carolina. In this inspection and test regime, the tested vehicle is operated until proper engine temperature is achieved. While the vehicle is operating at idle, a sample of the exhaust is analyzed for HC and CO concentration in the gas analyzers, and the results are recorded. If the vehicle does not pass the established emission limits, the vehicle then will be required to receive corrective action.

The term "idle inspection" is somewhat misleading since the vehicle is also operated at higher rpm (2,500) as part of the inspection test cycle. The test mode is more accurately described as a static or light-load test, as the vehicle engine is operated without benefit of vehicle road loads. It has been demonstrated that vehicle system malfunctions, which result in high emission characteristics at idle rpm, frequently contribute to high emissions over a typical load/speed range as measured by the standard Federal test. However, the sensitivity of idle testing can be improved by performing additional testing at higher engine speeds. The engine loads experienced during higher rpm operations provide an opportunity to measure the effectiveness of off-idle carburetor circuits and to detect additional malfunctions that may contribute to high emissions. During the idle test procedure, engine operations and emission measurements are accomplished at 2,500 rpm prior to performing idle measurements. This sequence provides the opportunity for engine temperature stabilization.

Instrumentation for the idle test function consists of the following equipment for each lane:

- Nondispersive infrared (NDIR) instruments with two detectors operated in parallel; one measuring HC, and the other CO.
- Gas sampling and handling equipment including a tail pipe probe, sample line, vapor condenser, particulate filter(s), sample pump, and appropriate valves for the check and calibration cycles and for purging the system. More detailed equipment specifications are given in Section 3-G of this report, dealing with quality assurance.

The following is a description of a typical idle test sequence and diagnostic information when the vehicle fails.

a. Pre-Test

Prepare vehicle and equipment for the test.

1. Test Equipment - Service, warm up, and calibrate HC/CO test equipment per manufacturer's specifications.
2. Test Vehicle - Verify engine is at normal operating temperature (warm up as required).
3. Hook-Up - Insert probe in exhaust pipe (driver's side if dual exhaust); hook up tachometer per manufacturer's instructions.

b. Test

Perform HC/CO and rpm measurements and compare to idle test standards.

1. 2,500 rpm - Operate engine in neutral at 2,500 rpm; record HC/CO.

2. Idle rpm - Operate engine at idle rpm (in drive if automatic transmission); record measurements.

a. Diagnostic Information

1. High HC - Indications are caused by ignition misfires, advanced ignition timing, exhaust valve leakage, and over-lean mixtures. Ignition misfires can be diagnosed by use of the oscilloscope; timing problems by use of timing light. Valve failure is indicated by cylinder balance testing with compression test verification. Lean misfire is caused by a too lean idle mixture setting or manifold vacuum leaks.

2. High CO - This can be caused by an abnormally restricted air cleaner, a stuck or partially closed choke, or a carburetor idle circuit failure. Rough or erratic idle can be caused by a PCV valve malfunction. Idle HC/CO failure/malfunction truth tables can be used as a guide to identifying failures.

3. Frequency of Inspection

All vehicles will be inspected on an annual basis as a part of the yearly registration procedures. This frequency is justified on the basis that it minimizes costs and maximizes public acceptance while maintaining a reasonably high level of emission reductions. The vehicle normally deteriorates to its pre-maintenance lvels in 6 to 9 months. (Ref. 15).

4. Types of Vehicles to be Tested

Initially, the coverage of the I/M program will include only the following LDV vehicle categories:

- Light-duty gasoline-powered automobile*

---

*Passenger cars or passenger car derivatives capable of seating 12 passenger or less.

- Light-duty gasoline-powered trucks, LDT_1 (less than 6,001 pounds)
- Light-duty gasoline-powered trucks, LDT_2 (less than 8,501 pounds)

All heavy-duty vehicles (greater than 8,500 pounds), diesel-powered light-duty vehicles, and motorcycles will be exempted from the I/M requirements. A provision may also be included to exempt vehicles from the required maintenance phase of the program if the necessary repair work would cost over $100 (1976 dollars). The effect of this exemption on the program, in terms of emission reduction benefits, is minimal as shown in Table 4-1.

5. Stringency Factor

Cost and benefit data presented in this report are based upon an initial stringency factor (or failure rate) of 35 percent. This implies that 35 percent of the vehicles tested will fail to meet standards and will require corrective repair work and retesting. A comparative study, cost and benefit information have also been presented for a various stringency factor (see Section 3-E). The determination of test standards which will produce the desired failure rate is discussed in detail in Section 3-E of this report. For implementation, the setting of standards will require an iterative approach in which initial standards are chosen from a previously operated program, such as California or New Jersey. As results of the program in South Carolina become available, the actual failure rate will be determined, and the standards should be adjusted accordingly.

6. Data Handling

Data will be collected with regard to emissions levels, repair activities and facility operations. Analysis of these data will be performed to ascertain emissions reduction cost-benefit relationships, patterns of malfunctions, the adequacy and accomplishment of required maintenance, the effectiveness of failure diagnosis based on emission reduction calculations and on the review of remarks received from the repair garages, and operational effectiveness. Each inspection station will be required to submit weekly records which provide statistics concerning inspections completed, vehicles rejected, complaints received and maintenance tasks performed. Data on repair costs and services performed would also be collected from the private garage sector. A statistical sample of these data will be collected, keypunched, and processed by means of

Table 4-1

EFFECT OF REDUCING THE MAXIMUM REPAIR COST (IN 1976 DOLLARS)
(Ref. 2)

MAXIMUM REPAIR COST	PERCENT OF FAILED REPAIRED		AVERAGE[a] REPAIR COST		AVERAGE[b] FUEL ECONOMY IMPROVEMENT		TOTAL EMISSION REDUCTION			
							HC		CO	
	Idle	Loaded	Idle	Loaded	Idle	Loaded	Idle	Loaded	Idle	Loaded
$150	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
$140	100	100	100	100	100	100	100	100	100	100
$130	100	100	100	100	100	100	100	100	100	100
$120	100	100	100	99	100	100	100	100	100	100
$110	100	99	100	94	100	100	100	100	100	100
$100	100	98	100	92	100	100	100	99	100	99
$90	99	97	97	90	99	100	100	98	100	98
$80	97	96	91	87	96	92	99	97	100	98
$70	97	94	91	82	96	83	96	93	97	95
$60	96	92	88	76	93	76	96	90	97	87
$50	94	88	85	60	91	77	94	87	95	81
$40	88	84	75	64	85	63	93	83	92	76
$30	86	77	72	56	85	70	90	78	85	68
$20	67	69	60	50	51	67	81	65	82	63

[a] At 100 percent all repair costs were included in establishing the average repair cost. Below 100 percent the maximum repair included only the noted percentage of repairs.

[b] At the stated maximum repair cost, the noted percentage of fuel savings was included in the average calculations. The possibility of further improvement in fuel economy is the difference between 100 percent and the noted percentage.

a centralized computer facility. Data summary reports will be generated and distributed to interested personnel in the State of South Carolina and the EPA.

7. Phasing Considerations

It is important to consider the necessary phasing of the implementation of an I/M program. The phasing considerations are constrained by the Clean Air Act Amendments according to the following key dates (Ref. Appendix A):

a.	January 1, 1979	- Submittal of I/M State Implementation Plan (SIP) revisions - Adoption of adequate legal authority for I/M
b.	June 30, 1979	- Adoption of legal authority for states where legislature meets in early 1979
c.	July 1, 1980	- Latest possible extension date for adoption of legal authority
d.	December 31, 1980	- Implementation of mandatory inspection and repair for states which adopted legislation by 6/30/79 and are implementing a decentralized program. Preferred private-garage option is in this category if they adopt legislation by June 30, 1979.
e.	December 31, 1981	- Implementation of mandatory inspection and repair for states which 1) adopted legislation by 6/30/79 and are implementing a new centralized program, or 2) adopted legislation by July 1, 1980 and are not implementing a new centralized program (preferred option (private-garage) is in this category.
f.	July 1, 1982	- Submittal of SIP revisions if standards are not going to be met by 12/31/82 (must contain provisions for I/M implementation)

g. December 31, 1982 - Implementation of mandatory inspection and repair for states which adopted legislation by 7/1/80 and are implementing a new centralized program
- Attainment of all standards except photochemical oxidant and/or CO

h. December 31, 1987 - Attainment of all standards

Another consideration which should be investigated for program phasing would be the possibility of establishing pilot test stations and an initial voluntary I/M program. A pilot program would allow: 1) evaluation and revision of the design study recommended inspection procedures and equipment specifications, 2) validation of the effectiveness of the diagnostic procedures in detecting causes for excessive emissions, and 3) refinement of the maintenance and repair procedures. Data required for these analyses could be provided by inspecting vehicles and evaluating selected samples of repaired vehicles. Additionally, the trial program data would be used to refine the exhaust emission standards established by the State of South Carolina, to provide the data base necessary to establish stringency standards for newer vehicles (e.g., 1978-1979 model years), and to supplement existing data on emission control problems such as tampering and special problems. The program could provide actual data on failure regimes and their changes because of local weather conditions. These data are necessary to realistically define I/M program manpower requirements. Throughput rate curves could be developed. The pilot program would also provide detailed local data on:

- The qualifications of emission repair personnel to understand the inspection lane diagnostic statements and recommended repair procedures.
- The qualification requirements of emission repair personnel
- Whether dealer, independent and service mechanics are sufficiently qualified to perform emission repairs.

- The identification of areas of deficiency and the development of requirements on the contents of training seminars to eliminate such deficiencies.

- It could be used at the start of the I/M program as one of the referee stations.

A typical time schedule for implementation of a pilot program is given in Figure 4-1.

8. Mechanic Training

The air quality benefit from the I/M program will be dependent, in part, on the ability of the service industry to properly perform the repair work necessary to lower emissions. Depending on the level of service industry training, emissions could be reduced just to the levels which would pass the I/M test or well below them. Some savings in repair costs may also result from the training since the mechanics would be familiar with the problems and the best solutions. Mechanics in the State of South Carolina presently have access to emission training courses through the vocational schools in the State. The instructors for these courses have generally received their training through an EPA-sponsored instructional program which utilizes the Colorado State University Motor Vehicle Emissions Control and Safety package. There is currently no existing program for training mechanics in the field. The EPA is currently working on a short (8-hour) course for these mechanics, but feels that the program will take about a year to develop. This time frame will fit in well with the requirements of I/M, and the State should fully support the EPA program. Support of this program will satisfy the EPA's minimum requirements for an I/M system and, if the program is successful, additional emission reduction credits can be claimed (Ref. 19). For a private garage system, the EPA also requires that a representative of each station must have received instruction in the proper use of emission testing instrumentation and vehicle testing methods and must have demonstrated proficiency in these methods.

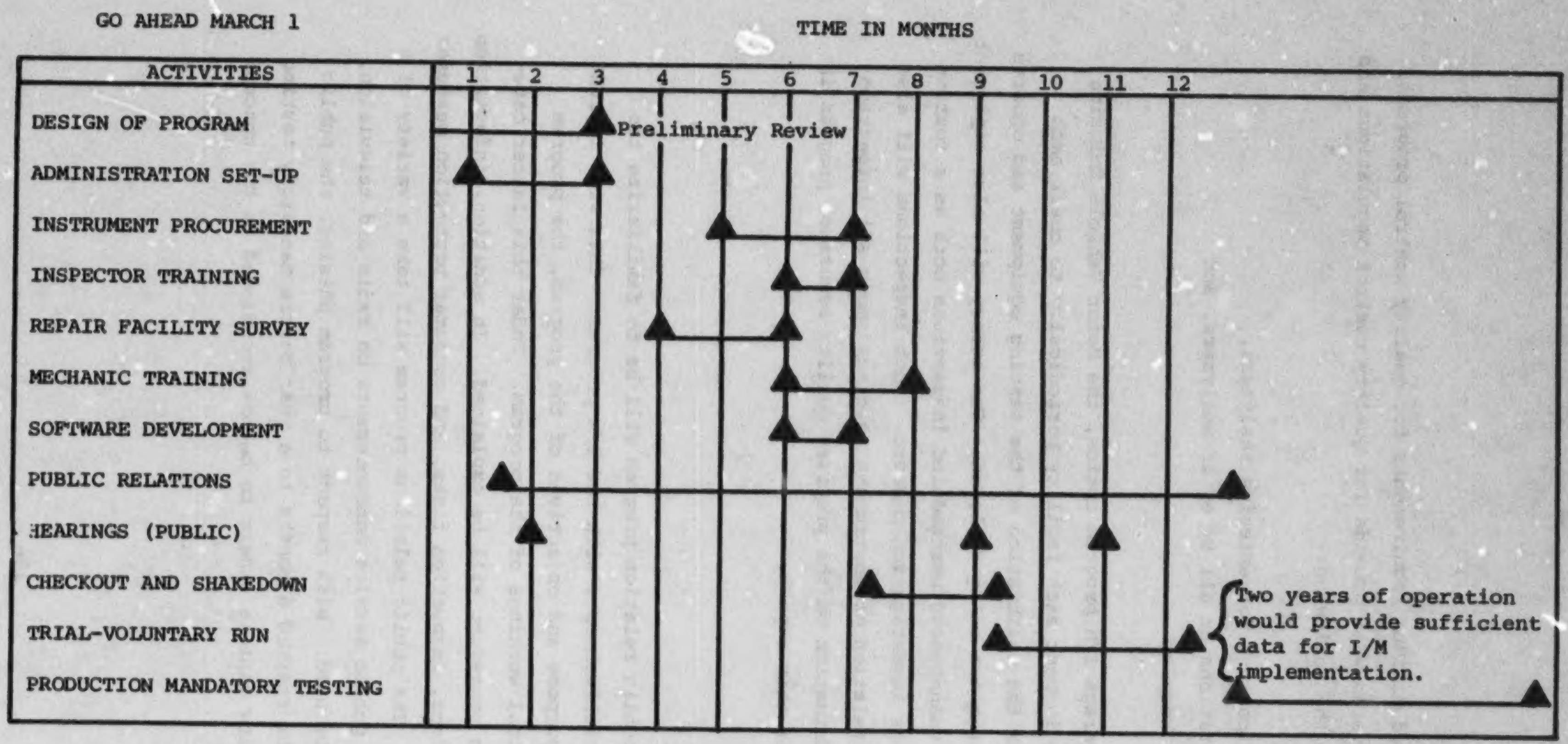


Figure 4-1

PILOT PROGRAM AT THE STATE TESTING CENTER TIMELINE IDLE TEST MODE

9. Quality Control

The EPA has specified minimum requirements for quality control programs. The South Carolina I/M system will provide for quality control regulations and procedures which include the following:

- Minimum specifications for emission analyzers,
- Required calibrations on all types of analyzers, and
- Minimum record keeping.

Under the private garage I/M program option, the Motor Vehicle Emission Control Office will also inspect each facility periodically to check each facility's records, check the calibration of the testing equipment and observe that proper test procedures are being followed. The agency will also implement an effective program of unannounced/unscheduled inspections both as a routine measure and as a complaint investigation measure. Such inspections will also be used to check the correlation of instrument readings among all inspection facilities. Further information on the proposed quality assurance program is given in Section 4.E.3 of this report.

10. Public Relations

The function of a public relation program will be to familiarize the public and the repair establishments with the I/M program. This will include the explanation of the purpose and objectives of the program, the program benefits, and the practical workings of the program. Under this latter category, the actual testing procedure will be explained. In addition, information regarding station locations, inspection times, and consumer protection measures will be made available. The public relations program will take a variety of forms. Advertisements, public service announcements on radio and television, and brochures will all be used. With respect to program phasing, the public relations program will be started 6 months to a year before mandatory testing is begun in order to allow vehicle owners to become accustomed to the concept of I/M.

11. Consumer Protection

The major requirements of a comprehensive emission control consumer protection program will include:

- designation of a lead agency for overall consumer protection responsibility,
- implementation of a consumer protection program,
- definition of local responsibilities, and
- provision for regulation of the repair industry.

The system will be made up of a number of programs:

- warranty protection program
- after-market parts program
- modified parts program
- recall/defects program
- consumer complaint resolution (field investigators)
- repair facility certification criteria

(See Section 4.E.2 for a more detailed description of the consumer protection system.) A fleet of mobile vans will be maintained by the State to act as "referee" testing units. Upon request of the consumer or station representative, a van will be dispatched which can perform simultaneous testing at any location in the region.

12. Enforcement

The enforcement mechanism for the I/M program will be tied in with existing motor vehicle registration procedures. The South Carolina Department of Motor Vehicles (DMV) provides for a fully computerized and efficient data-handling system that continuously processes detailed information on owner (name, sex, age, driving history, etc.) and vehicle (make, model, year). This information is constantly updated and is readily available to governmental agencies directly concerned with I/M program requirements. These factors identify the vehicle registration system as a likely candidate for an emission test enforcement control point. The vehicle registration system provides for an annual inspection process by making an emission test a necessary prerequisite for the successful completion of the registration process. Upon receipt of vehicle registration renewal application, the owner must obtain a Certificate of Compliance from a Certified Emission Test Station within a specified period of time (e.g., 90 days). A condition of noncompliance will result if the vehicle owner:

- o ignores emission test requirements
- o fails to pass established emission test standards
- o after failure of emission test, does not obtain the necessary repairs and retest.

Noncompliance will result in nonregistration of vehicle and, in effect, deny the right to operate the vehicle.

13. Legislative Requirements

The State of South Carolina will be required to enact legislation which enables the enforcement of an I/M program. In general, this legislative package will include two provisions. The first is a legal requirement that the owner or operator of a motor vehicle should not deliberately remove or inactivate the emission control devices presently required of automobile manufacturers. The second provision establishes a system of inspection and/or maintenance programs. This provision would address specific issues (i.e.; legal authority, fees, penalties) that should be incorporated into the enabling legislation.

B. COST METHODOLOGY AND DATA BASE

This section provides a description of cost methodology used in estimating all costs of implementation of an I/M program and the data base which were used for cost and benefits calculations.

1. Cost Methodology

I/M program costs were grouped into five categories, as shown in Table 4-2; major cost items of each category were also listed. Cost categories I, IV, and V included those resources and functional costs that were related to initial investment, capacity expansion and implementation. Operating costs covered the annually required costs that are necessary to operate the I/M program. Consumer protection costs covered costs of mechanic training program, public information program and enforcement.

General descriptions of each cost category are presented in the following paragraphs.

a. Test Equipment Costs

Equipment selected and recommended for the particular test methodology must be purchased and installed. Acceptance tests must be conducted before the facility certification. The test documentation would be supplied by the program management office. Additionally, it may be advisable for a team of qualified and trained technical inspectors to be available for guidance.

b. Annual Operating Costs

Annual operating costs include all costs associated with the actual operation of the I/M program. For the purpose of analyses, consumer protection costs are not included; rather they are identified as a separate cost category.

Facility Operation - For a private-garage operated facility, the operation cost include wages and overhead. Wages are compensation for personnel who inspect and test vehicles. The overhead need to cover equipment, facility maintenance, utilities, supplies, and taxes.

Support Costs - The costs included in this group reflect the overall program administration effort. Specifically, salaries of administrative personnel, office supplies, office rental, and data analysis cost are included.

Table 4-2
OUTLINE OF PROGRAM COST CATEGORIES AND ELEMENTS

- I. TEST EQUPMENT COSTS
  - 1. Instrumentation Costs
    - a. Primary test equpment
    - b. Ancillary equipment
    - c. Maintenance equipment

- II. ANNUAL OPERATING COSTS
  - 1. Facility Operation
    - a. Personnel costs
    - b. Maintenance and miscellaneous item costs
      - 1. facility
      - 2. equipment
  - 2. Support Costs
    - a. Administration
    - b. Data analyses
    - c. Training
  - 3. Quality Control Costs
    - a. Administrative supply costs
    - b. Maintenance and operation costs
    - c. Personnel costs

- III. CONSUMER PROTECTION COSTS
  - 1. Public Information Program
  - 2. Complaint Follow Up
  - 3. Spot Check
  - 4. Vehicle Test Scheduling Costs

- IV. INITIAL IMPLEMENTATION COSTS
  - 1. Bids Preparation and Evaluation
  - 2. Training Plan Development
  - 3. Document Preparation
  - 4. Administrative Support
  - 5. Initial System Certification

- V. OTHER CAPITAL COSTS
  - 1. Administrative Office Equipment
  - 2. Quality Control Equipment
  - 3. Consumer Complaint
  - 4. Vehicle Test Scheduling

Quality Control Costs - Quality control cost consists of certification and recertification of test stations, mobile unit operation, instrument maintenance, personnel costs, supplies, data analysis, and admininstrative cost pertinent to quality control operation.

Prior to receiving the first inspection vehicle, the total facility must be qualified and certified. It was previously stated that the approved equipment is certified after installation. Additional tests would be conducted on the total system of equipment, personnel, procedures, and documentation to assure uniformity on a statewide basis.

The quality control program requires mobile vans to calibrate all test equipment in each facility.

c. Consumer Protection Costs

This cost category include operating expenditures for mechanic training, public information, and enforcement programs.

Mechanic Training - The air quality benefit for an I/M program is dependent, in part, on the ability of the service industry to properly perform the repair work necessary to lower emissions. Thus, a proper training program would enhance benefits of emission reductions.

The cost of mechanic training can be defrayed through a charge for the training course. In the cost analysis, it is not included in the program cost.

Public Information - The experience with I/M program operation shows that there is a definite requirement for a vigorous public information effort. Cost of public information covers newspaper, television, and radio advertisements, pamphlet distribution, and public speech, etc.

Enforcement - Costs of enforcement include spot checks of in-use vehicles, salaries of enforcement officers, operation cost of enforcement vehicles.

d. Iniitial Implementation Costs

Implementation of an I/M program will require the expenditure of monies for noncapital items and services on a one-time basis prior to the actual start-up. Costs of this nature are difficult to define. They generally include initial administrative effort, development of standards and specifications, system checkout, and personnel training.

e. Other Capital Costs

This category covers initial capital costs which in general are not included in other categories. Cost items are administrative office equipment, quality control equipment, and enforcement.

This cost analysis will include estimation of costs in each category in Table 4-2 over 10 years. In order to caculate consumer fee charge, program cost that comprise the costs categories in Table 4-2 will be converted into uniform annualized cost. The fee is then calculated by dividing the total annualized costs by the average of vehicle population over 10 years. The fee assumes a free reinspection for each of the failed vehicles. The fee along with all other costs is expressed in 1978 dollars. To get fee in actual dollars, one must adjust for inflation. Detailed discussion is presented in Appendix E.

2. Data Base

The section is organized to provide detailed background data on program costs, geographical areas, personnel requirements, vehicle categories, test mode, enforcement, public relations, and benefits.

a. Unit Cost Related Data

The cost functions and their elements are presented in Table 4-2. All costs are based upon 1978 dollars. Where program costs are specified they are stated in constant dollars. They do not reflect an inflation factor.

Equipment Costs - Equipment recommended for a particular test methodology must be purchased and installed. The equipment and support instrumentation is interdependent with, and must be defined in terms of, the test regime and applicable exhaust emission standards. The inspection system for an idle mode testing facility should include an exhaust sample handling subsystem and analytical instruments.

Exhaust gases are extremely complex mixtures of hydrocarbons (HC), carbon dioxide (CO_2), carbon monoxide (CO), oxides of nitrogen (NO_x), aldehydes, particulates, water, nitrogen (NO), oxygen, hydrogen, and many other compounds. To accurately measure any single pollutant, the application of proper gas sampling techniques and careful sample handling treatment prior to instrument analysis are required. The basic consideration must be to obtain a sample of exhaust gas which is completely representative of the vehicle exhaust for the operating condition of interest.

It becomes necessary to selectively remove those materials and compounds that affect the absolute measurement of the subject pollutant without changing the concentration or characteristics of that pollutant. In a practical sense, this generally means reducing the water vapor level in exhaust gases and filtering out the particulates before passing the gas sample through a measuring instrument. Additionally, the sample handling system must also provide for the periodic input of zero and span check gases and calibration gases.

Sampling System Selection - The sample system for an idle inspection test mode may consist of a tail pipe probe, sample line, vapor condensor, particulate filter(s), sample pump, appropriate valves for the check and calibration cycles, and for purging the system.

The vehicle emissions pollutants that require monitoring are:

- Carbon Monoxide - The most commonly used method for CO measurement involves the use of nondispersive infrared (NDIR) instrument. These instruments are based on the principle that the infrared absorption spectrum of CO gas is sufficiently unique, compared to any other exhaust component gases, such that the measurement of infrared energy absorption is proportional to the concentration of the component of interest in the presence of other gases.

- Hydrocarbons - The analyses of hydrocarbons in automotive exhaust gas is complicated by several factors. Hydrocarbons are a complex mixture and their concentrations vary over an exceptionally wide range. The NDIR technology is the primary method presently in use for hydrocarbon measurements.

The equipment cost estimates used in this study were developed primarily from interviews with manufacturer's representatives. These interviews focused on identifying the equipment (i.e., type and model) required and the general level of skill needed to operate and maintain each. Specific costs are presented in Table 4-3. In the cost analysis, an average cost of $3000 will be assumed.

Annual Operating Costs - The annual operating costs of an I/M program include those costs associated with:

- Facility operation costs
- Quality control costs
- Support costs

These costs consist of the following break outs:

- Facility operation costs
  - -Personnel costs
  - -Utility costs
  - -Facility maintenance
  - -Supplies
  - -Insurance
  - -Property tax
  - -Equipment maintenance

Table 4-3
ADVERTISED PERFORMANCE SPECIFICATIONS OF EXHAUST EMISSION ANALYZER

MODEL	MANUFAC.	OPERATING PRINCIPLE	SPECIFICITY	RANGE	ACCUR.	TEMPERATURE RANGE	HUMIDITY	SAMPLE SYSTEM	INITIAL COST
Mexa 300A	Horiba	NDIR	HC/CO	0-400/2000ppm 0-21/10%	3% FS	32°F to 105°F	95% RH	Filter water separator	$ 2,395
1836	Barnes Eng. Co.	NDIR	HC/CO	0-400/2000ppm 0-2/10%	±3% FS	30°F to 120°F		Filter	2,356
8335C	Barnes Eng. Co.	NDIR	HC/CO	0-400/2000ppm 0-2/10%	±3% FS	30°F to 120°F		Filter	2,494
590	Beckman	NDIR	HC/CO	0-400/2000ppm 0-2/10%	12ppm 0.06%	35°F to 110°F		Filter water trap	2,300
EPA 75	Sun	NDIR	HC/CO	0-500/2000ppm 0-2.5/10%	±2.5% FS	32°F to 120°F		2 filters water trap	2,750
2001	Sun	NDIR	HC/CO misc. computer	0-2000ppm 0-10%	±3% FS			2 filters 2 water traps	17,440
7050C	Autoscan	NDIR thermocouple	HC/CO	0-500/2000ppm 0-2/10%	±2% FS			Filter	2,425
23170	Allen	NDIR	HC/CO	0-500/2000ppm 0-2.5/10%	3% FS			2 filters water traps	2,371
200 Auto-sense	Hamilton Test Systems	NDIR	HC/CO misc. computer	0-2000ppm 0-10%	±3% FS	35°F to 110°F	10% to 90% RH	Filter water trap	16,000
42-076	Marquette	NDIR	HC/CO	0-500/2000ppm 0-2.5/10%	±3% FS	35°F to 110°F	85% RH	Filter water trap	2,425
400	Beckman	FID	Total HC	0-1/10/100/1000ppm	±1&	32°F to 110°F	95% RH	Filter	2,820
951	Beckman	Chemi	NO/NO_x	0-10/25-10,000ppm	±0.5% FS				6,200

- Quality control costs
  - -Administrative supply costs
  - -Mobile unit operational costs
  - -Equipment maintenance costs
  - -Equipment replacement costs
  - -Personnel costs

- Support costs
  - -Administrative supplies
  - -Administrative personnel
  - -Administrative office rent
  - -Data analyses
  - -Fee collection and vehicle registration processing
  - -Consumer complaint[a]
  - -Public information program[a]
  - -Mechanic training[a]
  - -Enforcement[a]
  - -Personnel intermechanical training

[a] These costs are covered under consumer protection and enforcement.

Test Station Operating Cost - Current shop rate in the State ranges from $14 per hour to $22 per hour. An average of $18 per hour will be used in the analysis. This shop rate includes wages and overhead.

To estimate test station operating cost, the average output rate should be determined. For idle emission test, the average time for one vehicle inspection is 3.75 minutes (see Section 3.G). The operating cost is the product of shop rate and total number of vehicle inspected (including reinspection of failed vehicles) divided by the inspection time per vehicle.

Quality Control Operating Costs -

- Administrative - Supply Costs - Annual supplies for the quality control administration are estimated at $100 per person.

$$S_c = M_p (100)$$
$$= \$200 \text{ (\# mobile units)}$$

where:

S_c - supply cost

M_p = mobile unit personnel

- o **Maintenance and Operation Costs** - Annual costs for operations of mobile vans is based upon 25,000 miles per van at $.15 per mile.

$$M_m = 25{,}000 (\$.15) \text{ \# mobile vans}$$
$$= \$3{,}750 \times \text{ \# mobile vans}$$

- o **Personnel Costs** - Presented in Section 4.B.2.b.

Support Costs -

- o **Administrative Supplies** - Annual supplies for the adminstrative personnel are estimated at 2100 per person. For 20 administrative personnel the total cost is then $4,000.

- o **Administratrative Office Rent** - Annual cost for rental space is $0.40 per square-foot per month. The square-foot requirements per person is approximately 100-square feet at a monthly cost per person of $40.00, or a yearly cost of $480. For the 17 administrative personnel total yearly cost is estimated at $8,200.

- o **Administrative Personnel Costs** - The administrative personnel costs are presented in Section 4.B.2.b.

- o **Data Analyses** - Emission data collected will have to be reviewed and reports prepared covering various subjects as the State of South Carolina may recommend. Such coverage are:

  -Repair cost and status data-(current repairs, emission repairs, etc.)

-Emissions data status HC and CO
-Failure rates
-Warranty failures
-Complaint data
-Recall action
-Vehicle data
-Failure cause
-Retest status
-County status on emissions
-Operations effectiveness

From such a list it appears that monthly, quarterly, or yearly reports would involve a sizeable expense. To process all data associated with the above would cost in the order of $11,000 to $15,000. The associated cost to formalize the report are:

Technical layout and discussion	$50 per page
Typing and editing	$7 per page
Printing and collating	$0.10 per page

A 250-page report would cost $15,500 for preparation and publishing 50 reports. Total cost for complete quarterly reports with all noted items would be approximately $30,000 to $35,000. This could be reduced by publishing one major report with quarterly supplements. The annual cost would be approximately $80,000.

- o Fee Collection and Vehicle Registration - The fee collection of vehicle registration costs would be negligible after initial implementation costs, since they integrated into the vehicle registration costs.

- o Training - Personnel training is a continuing process. It is required to:

  -Indoctrinate/train new and replacement personnel

-Upgrade inspection personnel in new techniques and automotive changes

The costs noted here are for continuing instruction only, and costs are estimated as $200 per employee per year.

- Public Relations Costs - The costs for public relations is covered under Consumer Protection.

Consumer Protection Costs - This section presents estimated start-up and operating expenditures for public information and enforcement programs. Each program element will take advantage of existing state resources in the form of personnel services, equipment, and procedures. This will reduce the initial cost burden to institute needed consumer protection measures. The mechanic training is discussed in Section 4.E.5.

The organization of this section consists of three major subsections that separately examine consumer protection program elements. These subsections are arranged as follows:

- Public information program
- Complaint follow-up
- Spot-check program - enforcement
- Test scheduling and fee collection

Public Information Programs - To estimate the costs associated with a public information program, all states with experience in I/M public information programs were contacted. From contacts and additional research, a full range of possible activities was established and basic cost figures derived (Table 4-4). It is important to realize that the range of possible activities and comprehensiveness of public information programs varies considerably.

There are essentially two program elements that are widely used as I/M public information techniques. One element is the use of radio and television public service announcements, and newspaper advertisements. A second technique is the development of an information phamplet that is mailed, along with vehicle registration form to vehicle owners.

Table 4-4. INITIAL/ONGOING PUBLIC INFORMATION PROGRAM FOR ONE YEAR

PROGRAM TYPE	COST DESCRIPTION
A. ADVERTISEMENTS	
1. Public Service Announcements	
Newspaper	Full page advertisement 172-inch @ 1.65 per inch.
Television	1-minute public service announcements @ $40 per 10-second or $240 per minute.
Radio	1-minute service announcements @ $200 per minute includes radio and commission.
2. Pamphlet	
Development/preparation	Artist (logo and cover design) plus commission @ 20 hours.
Printing	Pamphlet printed on 20 lb paper, 1 color, foldout 7-1/2" x 11" (6 million copies).
3. Bumper Sticker	Printed on 6 lb all weather paper, 1 color. $60,000/4.5 million vehicles.
4. Transit aids	Space cost on 35 buses, $102 per month per bus (both sides).
B. PRESENTATIONS	
1. Films	Film development (30-minute information film). $25,000.
2. Slide Shows	Slide show development $500.
3. Guest Speakers	Use of existing public relations personnel minimizes cost.

To subsidize an initial and ongoing I/M public information program; it has been estimated that $0.25 per vehicle would generate revenues in excess of $134,596. These funds would finance various combinations of public information program.

Complaint Follow-up - Two major support services provided by the Consumer Affairs Office would involve complaint follow-up, and service industry field check. Annual cost estimates in providing such services are shown in Table 4-5. Estimated cost data include only major program considerations such as computer time sharing, personnel, investigative services, etc.

In order to estimate program costs, it was assumed that approximately 2500 consumer complaints would be registered annually. Most complaints would be resolved directly over the telephone. The more difficult complaints would require direct contact with a field investigators and the complaintant.

Spot-Check Program - If a random spot-check program was implemented, the estimated cost expenditures are shown in Table 4-6.

Table 4-6. ESTIMATED ANNUAL COST EXPENDITURES FOR STATE-OPERATED SPOT-CHECK PROGRAM

COST CONSIDERATIONS	COSTS (Thousands of Dollars)
Capital Costs	
i) Inspection vans	42
ii) Extra analyzers	6
Subtotal	48
Operating Costs	
i) Personnel	
2 state officers	37.9
4 inspectors	50.5
ii) Vehicular Expenses	3.1
Subtotal	91.5

It was assumed that a 5 percent pullover rate would provide statistically adequate samples of the in-use vehicle population. This implies that approximately 25,000 vehicles would be sampled every year.

Table 4-5

CAPITAL/OPERATING COSTS ASSOCIATED WITH CONSUMER COMPLAINT FOLLOW-UP AND SERVICE INDUSTRY FIELD CHECK

COST CONSIDERATIONS	COSTS
1. Captial	
(3) Complaint inspection cars	$ 5,000
2. Operating	
a. Computer time sharing[a] $600 per month	7,200
b. Personnel	
1 field investigators[b]	18,800
1 statistician	15,800
1 clerks	10,400
c. Vehicular	
gas/oil	1,000
insurance	300
Subtotal	$53,500

[a] Batch time sharing plus analyses.

[b] Minimum personnel required for handling consumer complaints over the telephone and investigating.

In order to calculate the number of mobile units required to test 5 percent of the vehicle population, it was estimated that an inspection team 1) state patrol officer and 2) emission inspectors could test 72 vehicles per day, or 18,720 vehicles inspections per year. This requires two mobile vans for an estimated $48,000 capital cost investments.

Manpower requirements include 2 police officers and 4 inspectors. Personnel operating expenses are $88,400 per year. Additional expenses include those operating expenditures associated with mobile vans are for vehicle servicing.

Vehicle Test Scheduling Costs

Table 4-7 enumerates capital and operating cost expenditures associated with vehicle notification, vehicle scheduling, etc. Capital expenditures would include only software development, since existing computer services would be utilized. Computer software includes programming time, batch processing, etc. Operating costs include processing registration files, computer time, vehicle owner notification and postage.

Table 4-7. ASSUMED COST EXPENDITURES FOR VEHICLE TEST SCHEDULING

COST CONSIDERATIONS	COST
A. Capital Expenses[a]	
Software development	$ 25,000
B. Annual Operating Expenses[b]	
Processing files 2,700	81,000
Computer time 18 hrs x $300/hr	5,400
Notification, IBM cards 538,400 cards	67,000
Postage $0.08/notification	43,000
Subtotal of operating expenses	$196,400

[a] Implementation cost only.

[b] Vehicle registration costs are not included in our analysis. These costs are considered in the current vehicle registration fee.

Implementation One-Time Costs (Start-Up) - This section identifies and estimates implementation one-time costs. These costs are those required during the planning and development phase of an I/M program.

- Bids Preparation and Evaluation - Costs were developed for preparation of equipment specifications, reviewing manufacture literature, contacting supplier, and for preparation and review of bid packages.

Idle Mode	
-Equipment specification	$3,000
-Bid package and distribution	2,500
-Bid reviewed and selection	3,750
Total Cost	$9,250

- Training Plan Development - Costs are for personnel planning, curriculum development, and class scheduling.

Idle mode	$3,500

Data were developed from course development in the State of California and from various training centers.

- Document Preparation - Costs are clerical, editorial, and reproduction assistance in preparing a document to record the plans, schedules and analytical results associated with the planning and development phase.

Document Preparation	
450 manhours x $20 per hour	= $ 9,000
Reproduction	= 1,000
	$10,000

- Administrative Support - Cost including administrative personnel support tasks during equipment purchase, personnel selection, system installation and checkout as:

250 hours x $30 per hour = $ 7,500

  - Initial System Certification - Prior to receiving and testing the first vehicle, the entire inspection system must be evaluated and tested to establish conformity to performance specifications. Station certification would consist of a statistical sample vehicle run to ensure satisfactory performance. The costs associated for initial system certification by test mode are as follows:

Idle Mode

1,250 manhours x $25 per hour = $31,250

Other Capital Costs - Other capital costs presented are:

- Administrative office equipment
- Quality control equipment
- Consumer complaint
- Vehicle test scheduling

Administrative Office Equipment - The capital costs associated with administrative office equipment (e.g.; desks, chairs, typewriters, bookcases, reference tables, etc.) is approximately $500 per person.

Quality Control Equipment -

- Mobile Unit - The mobile inspection audit system costs per vehicle are presented in Table 4-8. The mobile inspection system could also be used to:

-Support spot-check operation during van downtime.

-Referee activity in urban areas.

Table 4-8. MOBILE UNIT COSTS PER UNIT

EQUIPMENT	COSTS
1. Van	$12,000
2. Van conversion (electrical, cabinets, etc.)	4,000
3. Analyzer (NDIR)	2,540
4. Working gas (2-blend)	66
5. Tachometer	200
6. Gravity master gas cylinders (5)	740
7. Tachometer calibrator	200
8 Hand tools	1,000
9. Digital voltmeter	200
Total	$20,946

The calibration check will include a 5-point curve check using 1 percent gravimetric master gases, and correlation tests using the van engine and state-owned analyzers. The state-owned analyzers will have the same capability as the station analyzers. The costs as noted were developed from a dealer survey.

o State Testing Center and Referee Stations - Customer complaints will arise regarding the reliability of emission test results, especially in cases where a vehicle fails an emission test after the recommended repairs have been performed. In order to resolve complaints of this nature a referee station can be used. The use of a referee station will also provide an additional check on emission test facility instrumentation, engine diagnosis, and mechanic capability. The mobile test units would be used as the referee station. Upon receipt of a customer complaint and request for verification of emission test results, an appointment will be made to conduct the verification test at the test facility in question.

To avoid an overload on the system, specific criteria will have to be developed to single out complaints of possible validity for verification testing. For example, vehicles which have failed after the recommended repairs were performed and/or vehicles for which the recommended repair costs are above some predetermined level would be eligible for verification testing.

The costs of a the testing center is presented in Table 4-9. This unit is used in the costing of this report.

Table 4-9. STATE TESTING STATION EQUIPMENT COSTS

EQUIPMENT	MINIMUM SYSTEM (Load/Diag.)
Dynamometer with road load inertia weights	$16,453
Driver's Aid	5,000
Analyzer bench	16,000
Gases	870
Miscellaneous-barometer, wet & dry bulb	850
Total	$39,173

Capital costs for consumer complaints and vehicle test scheduling are presented in previous sections.

b. Personnel

Private garage-operated option has been selected for program implementation. However, the Department of Highway and Public Transportation would be the overall administrative authority. This office would be responsible for quality control and direct or indirect administration of the field stations as appropriate.

Administrative - This category includes primarily administrative support in the form of manpower, equipment, and supplies. There is one I/M program administrator. This program administrator will administer the inspection program with the support of a quality control administrator and a test administrator.

The Program Administrative Office would coordinate following functions as provided by the South Carolina Department of Highways and Public Transportation, or other departments as appropriate.

- Legal activity
- Financial including purchasing, contract development, and accounting
- Public relations and information program
- Technical reports development
- Mechanics training
- Operations and administrative personnel training
- Consumer complaint
- Fee collection and vehicle owner notification
- Certification/licensing of mechanics

The personnel required are presented in Table 4-10. The administrative personnel include the Program Administrator and staff, the Quality Control Administrator and staff, and the Testing Administrator and staff.

Quality Control Field Support - In addition to the administrative quality control staff, the quality control section would require the field personnel complement presented in Table 4-11.

Table 4-11. QUALITY CONTROL FIELD PERSONNEL AND YEARLY COSTS PER UNIT BASIS

PERSONNEL CATEGORY	NUMBER REQUIRED	SALARY + 25% BENEFIT FACTOR	TOTAL
Mobile Control Unit (Per Unit)			
Lead technician (instrument) II*	1	$15,568	$15,568
Technician I*	1	10,665	10,665
Total			$26,233

*Inspection Agents.

The mobile quality audit personnel requirements are necessary to provide the following service:

- Quality control audit of each station at least once every 3 months.

The following methodology was used to establish personnel requirements:

- A minimum of four stations would be checked per day. This based upon 1/2-hour test time and 2 hours travel time per station.

Table 4-10
I/M STATE PERSONNEL REQUIREMENTS AND SALARIES - FOUR-COUNTY

PERSONNEL CATEGORY	NUMBER REQUIRED	SALARY + 25% BENEFIT FACTOR	TOTAL
Program Administrator	1	30,500	30,500
Secretary	1	13,000	13,000
Clerk	2	11,000	22,000
Environmental Engineer II	1	27,000	27,000
Assistant Program Administrator (Quality control)	1	29,000	29,000
Clerk	1	11,000	11,000
Statistician	1	27,000	27,000
Assistant Program Administrator (Testing)	1	29,000	29,000
Clerk	1	11,000	11,000
Inspection Agents (Administrative)	2	15,000	30,000
Inspection Agents (Field personnel)	8	*	*

*Reference Table 4-11 for Field personnel salaries.

- Each mobile unit requires:
  -One lead instrument technician
  -One support technician.

- The number of mobile quality control units would depend upon the number of stations required to service the vehicles in the 4 non-attainment counties.

The quality control referee lane is required to provide the following services:

- To investigate consumer complaints.

- To institute development practices to improve operation effectiveness.

- To initiate new practices related to new control devices.

- To provide a diagnostic routine for establishing repair effectiveness and special problem review.

Support Personnel - Support services are required from the following areas:

- Highway Department Analysis Section (emissions analysis and yearly report activities).

- Consumer Affairs Office.

- Attorney Generals Office

- Public Relations Department

- Computer Services

- Personnel Department
  - -Recruitment
  - -Training service
- Public Safety Department
  - -Spot-check

The support service costs are presented in Table 4-12.

c. Geographic Area

The State of South Carolina has designated the following four counties as possible areas required an I/M program. These four counties are:

1. Richland
2. Lexington
3. Charleston
4. Berkeley

Air Quality - The State of South Carolina has provided background documentation that identifies geographic areas that presently violate air quality standards for photochemical oxidants (O_3), (Ref. 8).

The Clean Air Act Amendments (CAAA) of 1977 requires attainment of the primary ambient air quality standards for ozone and carbon monoxide by 1982. However, if these standards cannot be attained by 1982, an I/M program must be implemented and the standard attained by 1987.

d. Vehicle Projections

Vehicle registration data was analyzed and is presented in Table 4-13. The data was used as basis for vehicle population projections for 1982 through 1992.

Table 4-12
SUPPORT SERVICE COSTS

SUPPORT SERVICE	OPERATIONS COSTS	PERSONNEL COSTS
Analysis - yearly report	Ref. Page	Included in operations costs
Consumer affairs	Ref. Page	Included in operations costs
Attorney general[a]	$15,000 per year	Included in operations costs
Public information	Ref. Page	1 person 25% of the time at a cost of $1,200/month
Central computer	Ref. Page	Included in operations costs
Personnel[b]	$300 per new hire	Included in operations costs
-recruiting	1. .15 x # of personnel x $125	
-training	1. # of personnel x $50	
Spot check	Ref. Page	Included in operations costs
Mechanics training	Ref. Page	Course fee charged but no cost to program
Purchasing		As required.
Accounting including payroll		As required.

[a] Seven referrals per year each referral would require approximately 2 days of activity with one court appearance in 2 years - attorney cost are $200/day + court costs for a total cost of $15,000/year.

[b] 15% Personnel turnover and $50 per personnel continuing training (the salary of personnel is not included).

Table 4-13. LIGHT-DUTY VEHICLE REGISTRATION DATA AND PROJECTION

COUNTY	1977[a]	1982	1986	1991[b]
Lexington	87,795	113,306	134,565	164,800
Richland	155,428	188,208	215,525	253,100
Berkeley	42,706	57,207	69,289	86,900
Charleston	151,907	179,666	202,805	234,200
Total	437,836	538,387	622,184	739,000

[a] Registration data.

[b] Extrapolated from year 1986.

Source: State of South Carolina, Department of Highways and Public Transportation.

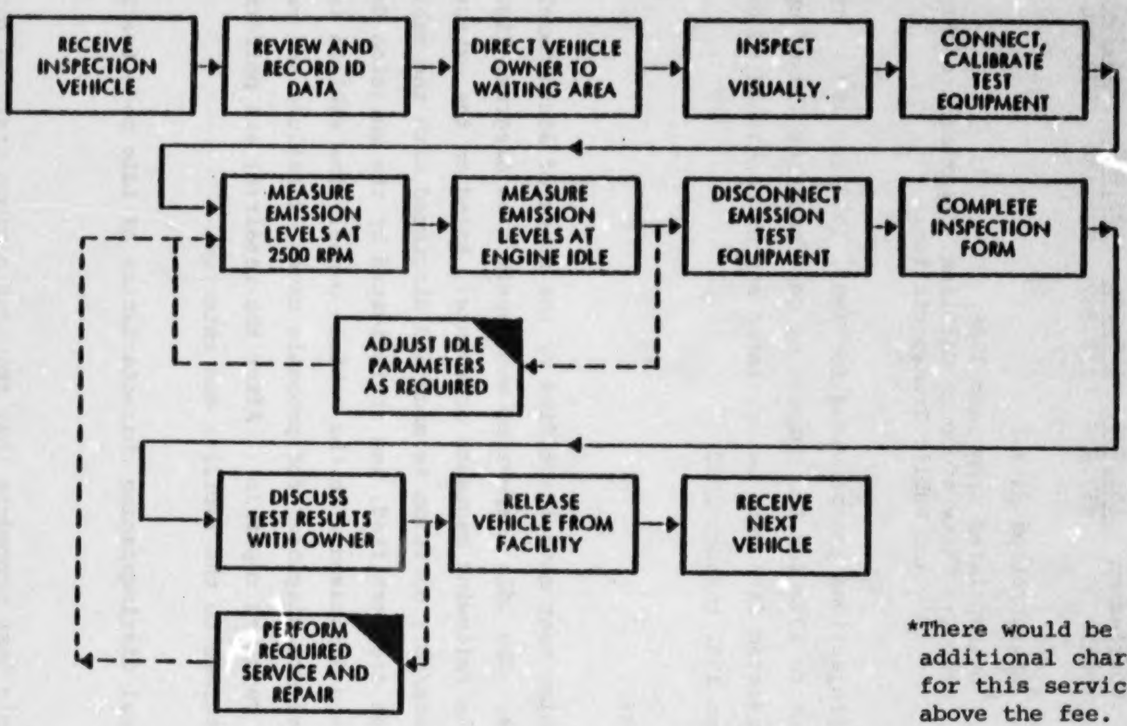
Vehicle projections are provided for 1982, 1987 and 1992. The projections are carried out to 1992 for the purpose of cost analyses (based upon 10-year operation) projected data were interpolated and extrapolated to get vehicle population from 1982 through 1992.

e. Test Modes

The emission test mode identified by the State of South Carolina is the idle test mode. The idle inspection and repair flow diagram, Figure 4-2, illustrates the following sequence of events. Based on the exhaust emission test data a pass/fail decision is made and discussed with the vehicle owner. Passed vehicles are certified, and if indicated by the emission data, impending malfunctions are discussed with the vehicle owner. The vehicle is then released. Failed vehicles are diagnosed for probable cause of failure and released to the owner for required repair(s). After the repair(s) are performed, the vehicle is returned to the facility and retested.

The general distinquishing characteristics of idle mode testing are as follows:

- Simple test procedure that requires minimum training for inspectors.
- Carburetor adjustments can be made during test.
- Diagnosis of some engine maladjustments and malfunctions.
- Can be duplicated by either public or private test systems.


RECEIVE INSPECTION VEHICLE
REVIEW AND RECORD ID DATA
DIRECT VEHICLE OWNER TO WAITING AREA
INSPECT VISUALLY
CONNECT, CALIBRATE TEST EQUIPMENT
MEASURE EMISSION LEVELS AT 2500 RPM
MEASURE EMISSION LEVELS AT ENGINE IDLE
DISCONNECT EMISSION TEST EQUIPMENT
COMPLETE INSPECTION FORM
ADJUST IDLE PARAMETERS AS REQUIRED
DISCUSS TEST RESULTS WITH OWNER
RELEASE VEHICLE FROM FACILITY
RECEIVE NEXT VEHICLE
PERFORM REQUIRED SERVICE AND REPAIR

*There would be additional charges for this service above the fee.

Figure 4-2

IDLE INSPECTION AND REPAIR FUNCTIONS

- Requires minimal test time and equipment.
- Malfunctions that occur under loaded conditions may not be detected.
- NO_x testing cannot be performed.

f. Administrative Option

The State of South Carolina has designated that the testing will be administered by the private garage (decentralized system).

The problem inherent in this program is that the parties doing the testing and repair is the same person. Inherently if one separates the two you have a quality control check of the operations. To overcome this problem, the State of South Carolina should institute a vigorous quality control check of all safety inspection stations. This inspection should be on random basis and should be completed at least four times per year.

Personnel Requirements - The state personnel requirements are minimal and are noted in Table 4-10.

Program Flexibility - Regarding personnel policies, great flexibility exists with private garage systems. If program manpower requirements change, a private garage responds readily.

g. Enforcement

The enforcement mechanism for the I/M program will be tied in with existing motor vehicle registration procedures. The State of South Carolina Motor Vehicle Division provides for an efficient data-handling system that continuously processes detailed information on owner (name, sex, age, driving history, etc.) and vehicle (make, model, year). This information is constantly updated and is readily available to governmental agencies directly concerned with I/M program requirements. These factors identify the vehicle registration system as a likely candidate as an emission test enforcement control point. The vehicle registration system provides for an annual inspection process by making an emission test a necessary prerequisite for the successful completion of the registration process. Upon receipt of vehicle registration renewal application, the owner must obtain a Certificate of Compliance from a certified emission test station within a specified schedule period of time of 1 month. A condition of noncompliance will result if the vehicle owner:

- Ignores emission test requirements
- Fails to pass established emission test standards
- After failure of emission test, does not obtain the necessary repairs and retest.

Noncompliance will result in nonregistration of vehicle and, in effect, deny the right to operate the vehicle.

An optional random spot-check program provides an additional enforcement measure by incorporating vehicle pullover techniques with emission testing. This program may provide statistically adequate samples of the in-use vehicle population in order to gain information on tampering and program effectiveness.

h. Public Information

The function of a public information program is to familiarize the public and repair establishments with an I/M program. This would include explanations of the purpose and objectives of the program, the program benefits and the operation of the program. Under this latter category, the actual testing procedure should be explained. In addition, information regarding station locations, inspection hours, and consumer protection measures should be presented.

The public information program could take a variety of forms. Advertisements, public service announcements on radio and television, newspaper, and information pamphlets. Table 4-14 presents estimated cost data relating to:

- Pamphlet preparation and distribution
- Advertisements (e.g., billboards, newspaper, ads, etc.)
- Presentations (e.g., speeches, films, etc.)

In addition, funds needed to finance a comprehensive informational program was placed on a per vehicle basis.

i. Benefits Data

Emissions Standards - The I/M emission standard (cut point or stringency factor) was established by communications from the State of South Carolina at 30 to 35 percent.

The Appendix N (FR 24(89): 22177-22183, May 2, 1977; Ref. 19) sets forth the emission reductions for carbon monoxide (CO) and hydrocarbons (HC).

Table 4-14 presents a typical HC emission factors derived from Mobile 1 Program (Ref. 20) using 49-State data.

The methodology used to calculate emissions reductions is as follows:

$$\text{Total Emissions Reductions} = \sum_{i}^{n} \frac{\text{No. Vehicles Each Class} \times \text{Emissions Credits} \times \text{Average Emissions} \times \text{Miles/Year}}{907{,}184 \text{ gr/ton}}$$

where n is class of vehicle, LDV, LDT1, and LDT2, (category of vehicle established by the State of South Carolina).

The average emissions as established through Mobile I routine is adjusted for the following features:

- Emission factor data
- Vehicle types
- Temperature - 75°F
- Speed input
- Vehicle miles traveled
- Speed/temperature/operating mode correction factors

Table 4-14

MOBILE 1 OUTPUT FOR EMISSION FACTORS FOR THE YEAR 1987

```
Total HC Emission Factors Include Evap. HC Emission Factors

                            Veh. Type:  LDV   LDT1   LDT2   HDG    HDD    MC
Cal. Year: 1987     Temp: 75.0(F)       .803/ .058/ .058/ .045/ .031/ .005
Region: 49-State    19.6:19.6/19.6/19.6 MPH (19.6)     20.6/ 27.3/ 20.6

Composite Emission Factors (gm/mile)

                 LDV     LDT1    LDT2    HDG     HDD     MC     ALL MODES
   Total HC:     2.24    3.71    5.12    13.11   3.41    1.40     3.02
   EVAP  HC:     .31     .41     .73     .83     0.00    .03      ----
Exhaust  CO:     20.46   40.19   50.17   166.44  27.76   6.96     30.06
Exhaust NOx:     1.64    1.97    2.59    8.15    13.56   .25      2.37

Hot Stabilized

   Idle  HC:     .53     1.15    1.71    2.86    .30     .61      .73
   Idle  CO:     5.99    10.77   17.92   38.29   .67     1.67     8.23
   Idle NOx:     .47     .21     .20     .02     .67     .02      .42
```

- Credit allowance from Appendix N
  - -air conditioning
  - -extra loading
  - -trailer loading
  - -humidity
- Vehicle age distribution

C. COST ANALYSIS

This chapter presents cost analysis for a private garage-operated idle mode test facility system for the South Carolina's vehicle I/M program. The geographic areas consist of 4 counties as selected by the State Vehicle categories under the I/M program include passenger cars, light-duty trucks (<8,501 lb). HC and CO emissions would be checked against an emission standard established to correlate to a 35 percent stringency factor. The enforcement mechanism is the annual vehicle registration.

The analysis assumed that existing privately-owned facilities would perform vehicle emission inspections under license from the state. Automotive service could be performed on-site if requested by the vehicle owner. Individual garages would purchase the prescribed test equipment and would perform the required emissions test for a fee regulated by the state. The fee charge should be sufficient to cover personnel cost, depreciation, and appropriate overhead costs associated with the emission inspection facility.

1. Facilities Requirements

a. Facility Capacity

The State of South Caroline has an on-going vehicle safety inspection program that is performed in the private garages. At present, there are 330 privately-owned service stations in the safety program in areas of Berkeley and Charleston Counties, and 318 stations in areas of Lexington and Richland Counties. Current safety inspection fee is $2.50 per vehicle.

b. Mobile Van Requirements

There will be four equipped mobile vans required for quality control purposes.

c. State Testing Center

One state testing center will be established to handle consumer complaints which require diagnostic inspections.

2. I/M Program Costs

a. I/M Program Costs

The major cost components for the four-county and statewide options are summarized in Table 4-16. The costs are identified as to state costs necessary to administer and conduct surveillance of the private-garage program, and operation and capital costs assigned to the private garage.

1. Four-County Option - It has been estimated that 671 private garages, distributed in the four counties as noted in Table 4-15 will actively participate in the I/M program. This will require a 10-year expenditure by the private garages of $4.0 million and $9.9 million for test equipment and facility operations, respectively. During this same period, the State will expend $4.9 million for capital, operation, and implementation costs. Total I/M expenditures by state and private garages for a 10-year program duration is estimated at $18.9 million.

   The private garage capital/expenditure of 4.0 million is the accumulated first time instrumentation costs of $3,000 and a 5 year replacement cost for a total of $6,000 per private garage - (6,000 x 671 = $4 million). The private garage-operation cost of 9.9 million are for the 671 private garages over the 10-year program at an operating cost per private garage over the 10 years of $14,800 or an average

Table 4-15.

COSTS OF SOUTH CAROLINA I/M PROGRAM - FOUR COUNTIES OPTION
($1,000 1978 Dollars)

CATEGORY	1982-1986 State	1982-1986 Private Garage	1987-1991 State	1987-1991 Private Garage	TOTAL State	TOTAL Private Garage
I Test Equipment Costs[a]	0	2,013.0	0	2,013.0	0	4,026.0
II Operating Costs						
Facility Operation	0	4,562.9	0	5,351.6[b]	0	9,914.5
Administrative Support	1,616.5	0	1,616.5	0	3,233.0	0
Quality Control	612.0	0	612.0	0	1,224.0	0
III Initial Implementation Costs	61.5	0	0	0	0	61.5
Public Information	200.0	0	0	0	0	200.0
IV Other Capital Costs						
Administrative Office Equipment	8.5	0	0	0	8.5	0
Quality Control Equipment	119.0	0	0	0	119.0	0
Consumer Protection	78.0	0	0	0	78.0	0
TOTAL	2,695.5	6,575.9	2,228.5	7,364.6	4,924	13,940.5
TOTAL STATE & PRIVATE GARAGE	9,271.4		9,593.1		18,864.5	

[a] Number of private garages participations in the program are:

Berkeley County	47
Charleston County	235
Lexington County	124
Richland County	265

[b] Facility operation costs increased to compensate for increase in the vehicle population.

of $1,500 per year. Therefore, the total average cost per private garage per year is $2,200.

The state costs of $4.9 million or an average of $40,000 per year over the 10-year program is for 3.2 million operating costs for administrative support analysis of data, prepare reports and administer the program including consumer protection, 1.2 million for quality control of 671 private garages, $200,000 for one time public information program, 1.2 million for quality control equipment, 8.5 thousand for office equipment, $78,000 for vehicle for complaint investigation and software development for vehicle scheduling, and one time cost associated with vehicle scheduling.

3. Consumer Fee Calculation

The ideal fee should be justified on the basis that it is sufficient for the state and private garages to cover all necessary expenses for the management and operation of the I/M program. The consumer fee charge determined in this report will be the total annualized cost burden shared by each vehicle owner.

Annualized costs of the I/M program option are determined by amortizing capital-related costs, test equipment, initial implementation, and other capital as defined in Table 4-16. Since test equipment has an average of 5 years of life expectancy, it is amortized over 5 years. Other capital-related costs are amortized over 10 years of the I/M program.

Assuming that the state's cost of capital is 6 percent per year, amortization factor is 0.2374 for test equipment and 0.1359 for other capital-related items.

Table 4-16 presents annualized costs of the I/M program. Total annualized cost would be $1.98 million per year. The state would be required to spend $0.51 million, while the private garages would expect annual cost of $1.47 million.

Table 4-16. ANNUALIZED COSTS OF I/M PROGRAM[a,b] - FOUR COUNTIES
(1978 DOLLARS)

CATEGORY	TOTAL AMORTIZED COST[c]	AVERAGE ANNUALIZED COST ($/YR)
I. Test Equipment Cost private garage	$2,013,000 x 0.2374 x 5[d] + $2,013,000 x 0.2374 x 5[d] = $4,779,900	$4,778,862/10 = $477,900
II. Operating Costs		
private garage		$9,914,500/10 = $991,500
state		$3,233,000 + 1,224,000/10 = $445,700
III. Initial Implementation Costs - state	$61,500 x 0.1359 x 10 = $83,600 $200,000 x 0.1359 x 10 = $272,000	(83,500 + 72,000)/10 = $35,600
IV. Other Capital Costs - state	(8,500 + 119,000 + 78,000) x 0.1359 x 10 = $279,300	$279,300/10 = $27,900 27,900
Total - State		$ 509,300
Private Garage		$1,469,400
State and Private Garage		$1,978,000

[a] All costs are rounded off to hundred dollars

[b] Basic cost data is taken from Table 4-15.

[c] Amortization factor (F) is determined by the formula

$$F = \frac{2(1+i)^n}{(1+i)^{n-1}},$$ where i is the cost of capital (=6%) and n is the number of years

For equipment amortization of 5 years, F = 0.2374
For capital amortization of 10 years, F = 0.1359

[d] The equipment life is considered to be 5 years, therefore, it is required to replace equipment after 5 years.

NOTE: Fee Calculation

$$\text{private garage share} = \frac{\$1,469,400}{622,200 \text{ vehicles}} = \$2.36$$

$$\text{state share} = \frac{\$509,300}{622,200 \text{ vehicles}} = \$0.81$$

TOTAL FEE $3.17

Using the vehicle population of 622,200 in year 1986, consumer fee charge (as presented in Table 4-17) was calculated by dividing annualized cost from Table 4-16 by the average vehicle population.

Table 4-17. CONSUMER FEE

Fee	State's Share	Private Garage's Share
$3.17	$0.81	$2.36[a]

[a] This fee does not include any service to the vehicle being inspected.

D. BENEFITS

This section presents an analyses of benefits derived from private garage-operated I/M program. Particular attention is given to the following:

- Expected reductions in emissions
- Fuel savings
- Effect on vehicle performance and vehicle life
- Failure rates and emissions reductions
- Estimated repair costs
- Value of warranty repair work performed

The primary objective of an I/M program is to reduce HC/CO emissions in response to nonattainment air quality levels for oxidants. Important secondary benefits as noted above would result from improved maintenance to the motor vehicles inspected in the program.

1. Emissions Reduction

The major benefit derived from the implementation of an I/M program is the reduction of hydrocarbon and carbon monoxide emission from motor vehicles in nonattainment air quality areas. The option studied and their predicted results for Berkeley, Charleston, Lexington, and Richland Counties were as follows:

- Private garage-operated emission test stations.

- Implement an in-use mechanic training program - 4 percent greater hydrocarbon reduction and 10 percent greater CO reduction than the basic I/M configuration.

The methodology used to estimate average emission reduction was based on available computer algorithms, specifically Mobile 1 Routine (Ref. 20). The Mobile 1 computer package was tailored to the needs of South Carolina by adjusting the following features (Ref. 16):

- Emission factor data - 49 state
- Vehicle types - LDV, LDT1, LDT2
- Temperature - 75°F
- Single-speed input - variable
- Vehicle miles traveled - South Carolina data
- Speed/temperature/operating mode correction factors - South Carolina data
- Credit allowance from Appendix N

-air conditioning	0.66
-extra loading	.04, 0.20, 0.25
-trailer loading	.02
-humidity	75 percent

- Vehicle age distribution - South Carolina distribution

A recent report by Engineering Science entitled "South Carolina Highway Emissions" (Ref. 21) provides estimated emission reductions using Mobile 1 Programs. Table 4-18 illustrates the typical program output.

Table 4-18. MOBILE EMISSION FACTORS BERKELEY COUNTY, 1977 NO I/M

```
                              Veh. Type:  LDV  LDT1  LDT2  HDG   HDD   MC
Year: 1977     Temp: 75.0(F)           0.716/0.077/0.037/0.035/0.134/0.001
Region: 49-State     50.0:50.0/50.0/50.0 MPH (50.0)     10.0/ 10.0/ 10.0
  AC: 0.66  XLoad:   0.04    0.20    0.25  Trailer:  0.02   ABSHUM: 75.00

                     COMPOSITE EMISSION FACTORS (GM/MILE)

                  LDV      LDT1      LDT2      HDG       HDD       MC      ALL MODES
Nonmeth HC:      4.37      4.75      6.50     10.75      2.35     6.28       4.43
   EVAP HC:      2.06      2.22      3.23      2.56      0.0      1.60        --
Exhaust CO:     28.51     30.31     32.22    138.15     14.14    18.01      30.69
Exhaust NO:      4.22      4.20      6.82     13.46     23.87     0.16       7.26
```

Emission levels developed by MOBILE 1 program, presented in Tables 4-19 and 4-20, detail HC/CO emission levels without I/M; with I/M; and percent emission reduction from I/M implementation; for county and statewide geographic options.

This information was provided for 1982 and 1987 I/M program years using 1977 as a base year. The second column for HC and CO shows total emissions in 1977. The third and sixth columns show emissions expected in 1982 and 1987 without an I/M program. The lower figures for both years are attributable to the Federal Motor Vehicle Emission Control Program (FMVCP). The fourth and seventh columns show the amount of emission reduction that would occur with FMVCP and an I/M program. The fifth and eighth columns show the actual percent emission reduction that may be achieved through implementation of an I/M program. In all instances, the percent reduction for each county closely approximates percent reduction values achieved over the entire state.

2. Fuel Savings

The amount of fuel saved by instituting a mandatory vehicle inspection and maintenance program is a function of many variables. The following parameters are of particular importance; vehicle miles traveled (VMT), fuel efficiency, total vehicle population and stringency factor.

A 3.8 percent fuel economy improvement, per failed vehicle per year (as established from California programs), was used in this study to calculate fuel and dollar savings for the I/M program options.

Table 4-19. HC EMISSION REDUCTION WITH AND WITHOUT IMPLEMENTATION OF I/M PROGRAM FOR 1977 (Base Year), 1982, AND 1987 (Tons Per Year)

	1977	1982			1987		
COUNTY	WITHOUT I/M	WITHOUT I/M	WITH I/M	% REDUCTION	WITHOUT I/M	WITH I/M	% REDUCTION
1. Lexington	5,961	3,962	3,748	5	2,313	1,793	22*
2. Richland	10,376	6,148	5,790	6	3,499	2,670	24*
3. Berkeley	2,421	1,527	1,434	6	919	697	24*
4. Charleston	9,205	5,335	5,028	6	2,920	2,216	24*
Total	27,963	16,972	16,000	6	9,651	7,376	24*
Statewide	89,662	56,086	52,785	6	31,870	24,358	23*

SOURCE:: Ref. 5

*Although the 1987 percent reduction does not meet the EPA reduction of 25 percent as specified in Reference 1, the percent reduction could be within the error potential of the MOBILE1 program and the State of South Carolina should not have any difficulty in meeting the required percent reduction with the planned I/M program.

Table 4-20. CO EMISSION REDUCTION WITH AND WITHOUT IMPLEMENTATION OF I/M PROGRAM FOR 1977 (Base Year), 1982, AND 1987 (Tons Per Year)

	1977	1982			1987		
COUNTY	WITHOUT I/M	WITHOUT I/M	WITH I/M	% REDUCTION	WITHOUT I/M	WITH I/M	% REDUCTION
1. Lexington	43,973	38,548	32,552	16	25,903	17,459	33
2. Richland	79,829	60,983	51,112	16	39,160	25,944	34
3. Berkeley	17,581	14,684	12,278	16	10,116	6,609	35
4. Charleston	71,793	53,356	44,626	16	32,715	21,456	34
Total	214,176	167,571	140,568	16	107,894	71,468	34
Statewide	683,540	552,835	463,754	16	356,300	236,010	34

SOURCE: Ref. 5

These parameters are related in the following way.

$$G_s = \left[(V_m/F_e) \times F_c \times (T_v \times S_f) \right]$$

where:

G_s = Fuel gallons saved
V_m = Vehicle miles traveled per year
F_e = Fuel efficiency, miles per gallon, fleet average
F_c = Fuel consumption per failed vehicle = 0.038
T_v = Total vehicle population
S_f = Stringency factor = 35 percent

The estimated number of gallons saved are then used in the following calculation to determine fuel savings in dollars.

$$F_s = (G_s) \times (G_p)$$

where:

F_s = Fuel savings in dollars
G_s = Gallons saved
G_p = Estimated price per gallon ($0.70/gallon)

Differences in the above variables will directly influence fuel savings, therefore, the following assumptions are noted:

- 11,500 miles traveled per year (V_m)
- 15 miles per gallon (F_e) fleet average in 1982, 24 miles per gallon fleet average in 1987

As shown in Table 4-21, the four-county I/M option would save 5.48 million gallons of fuel in 1982 and 4.07 million gallons in 1987. At $0.70 per gallon, vehicle owners would save $3.84 million and $2.85 million for 1982 and 1987, respectively. If coverage is extended to include the entire state, motorists would save 18.10 million gallons in 1982 and 13.45 million gallons in 1987. This amounts to $12.67 million and $9.41 million for 1982 and 1987, respectively.

Table 4-21. ESTIMATED ANNUAL FUEL ECONOMY BENEFITS FOR FAILED VEHICLES

	1982 SAVINGS			1987 SAVINGS		
OPTION	Fuel Mil. Fal	$ Million	Per Vehicle	Fuel Mil. Gal	S Million	Per Vehicle
1. Four-County (Lexington, Charleston, Berkeley, Richland)	5.48	$ 3.8	$7.14	4.07	$2.85	$4.46
2. Statewide	18.10	$12.67	$7.14	13.45	$9.41	$4.46

In terms of fuel savings per vehicle, it would be $7.14 in 1982 and $4.46 in 1987. Less fuel savings per vehicle in 1987 is anticipated because of higher fuel efficiency of automobiles. Moreover, the motorist who repairs his failed vehicles will realize a saving in fuel cost as an offset to the repair cost.

3. Effect on Vehicle Performance and Vehicle Life

The impact of I/M on these considerations is difficult to quantify. The studies to date have not been conclusive. They have centered on the way I/M affects short and long run vehicle deterioration curves. The short run deterioration curve reflects the rate at which a vehicle deteriorates after it has been tuned (Figure 4-3), while the long run curve reflects the overall degradation in vehicle performance that occurs as it ages (Figure 4-4). Both curves, especially the short run deterioration curve, influence vehicle performance while the slope of the long run curve is more likely to be the primary determinant of vehicle longevity. To the extent that I/M influences the short run curve, it should have a positive impact on vehicle performance. If an engine remains within the manufacturer's specifications, it should perform at a higher level due to I/M.

The influence on performance and longevity resulting from I/M's impact on the long run deterioration curve is unknown. It seems sensible that a properly maintained vehicle will experience less wear than if it is not maintained to manufacturer's specifications. Assuming this relationship is true, I/M should have a positive effect on vehicle life. The repair of a vehicle can reduce

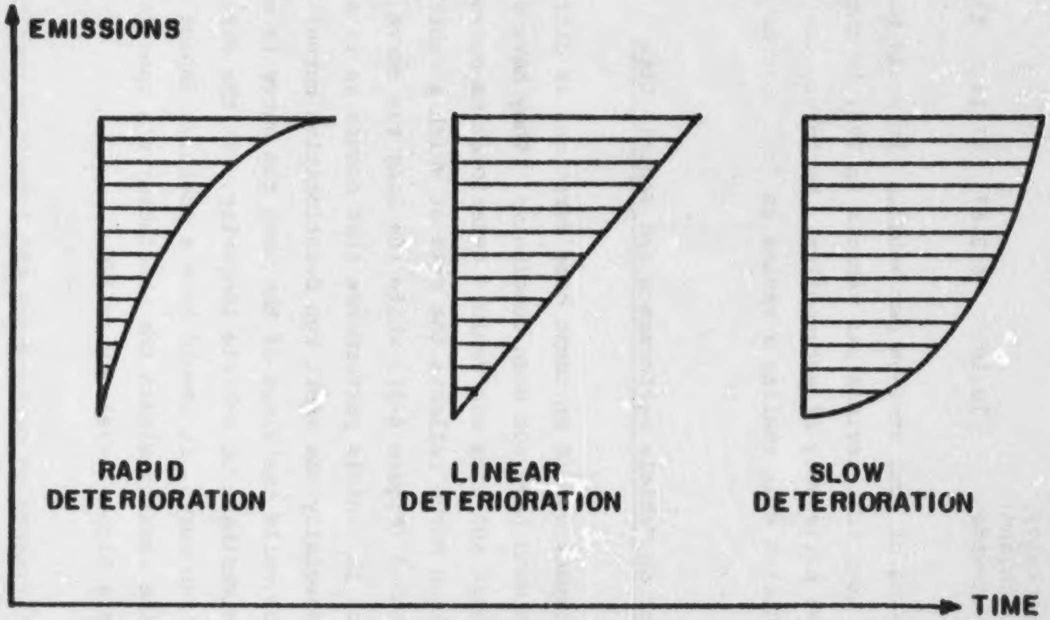


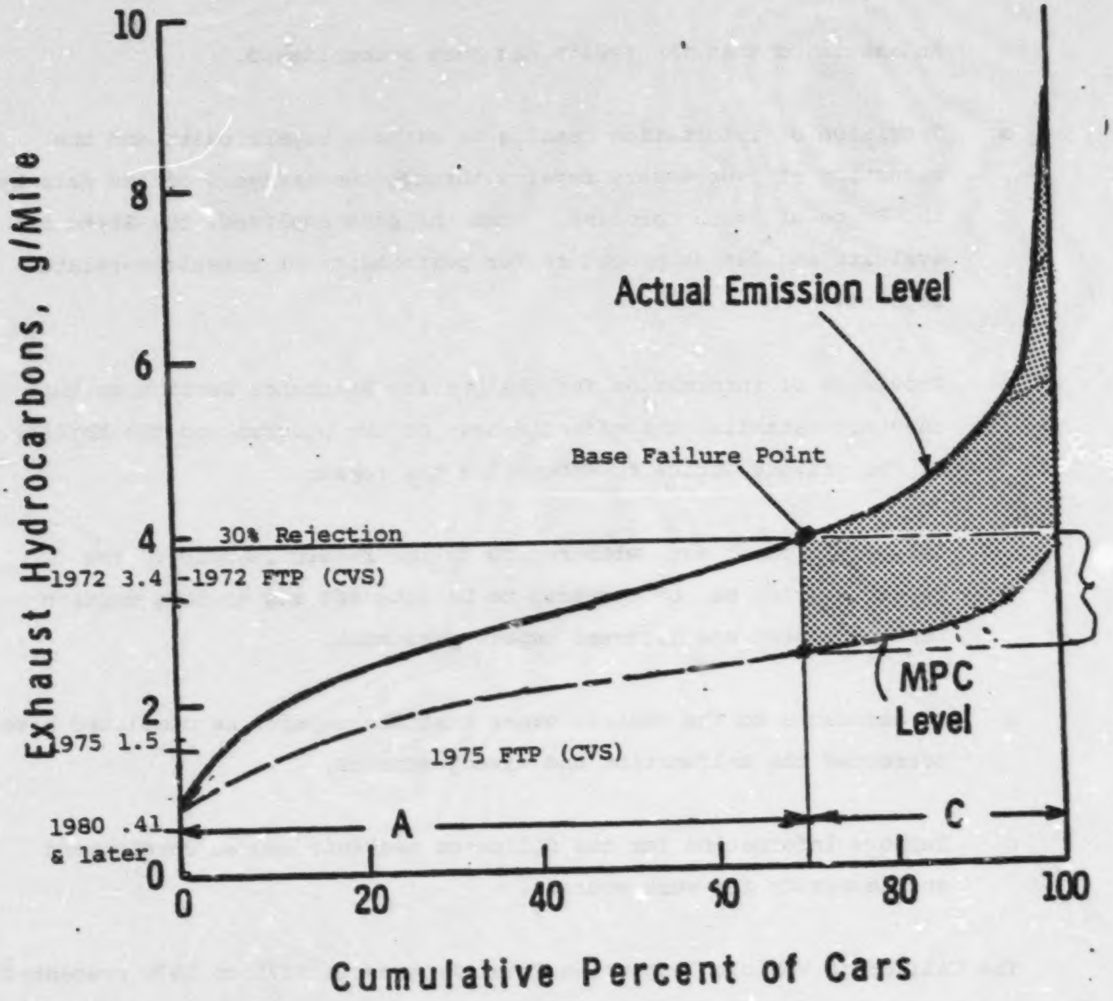
Figure 4-3

POSSIBLE POST MAINTENANCE DETERIORATION FUNCTIONS SHORT RUN

Figure 4-4

ACTUAL EXHAUST HYDROCARBON LEVELS VERSUS MPC* LEVELS

Cars With Exhaust Controls



*Minimum Pollution Capability - Life cycle deterioration curve without any major repair.

NOTE: The MPC level curve can vary drastically from vehicle-to-vehicle. It depends upon abuse of the vehicle over heating, over loading, etc.

emissions to minimum pollution capability (MCP) line after repair to manufacturers' specification level.

4. Retest of Failed Vehicles

The benefits that will accrue from a retest of a failed vehicle after repair are:

- An assurance that the repair has been accomplished.
- Provision of information leading to minimum repair costs and the reduction of unnecessary repairs through the analysis of the data by the State of South Carolina. From the data analyzed, the State can evaluate and define procedure for performance of emissions-related repairs.
- Provision of information for the Quality Assurance Section so that they may establish the effectiveness of the program and the ability of the private garage to accomplish the repair.
- The provision of data with regard to the repair industry. The repair station may be required to be licensed and to have certain test equipment and licensed repair personnel.
- An assurance to the vehicle owner that the repairs as completed have corrected the malfunction and misadjustments.
- Support information for the follow-on mechanic course development and necessity for such courses.

The California Vehicle Inspection Trial Program in 1975 to 1976 presented the following statistics:

- 82 percent failed vehicles passed the retest
- 6 percent passed the subsequent reinspection

- 64 percent had correct repairs to correlate with failure status
- The California Air Resourcs Board Surveillance Program indicated that mechanics experienced considerable confusion in interpreting and carrying out the repairs procedures.

From this data it is evident that there is a necessity to follow-up on repair activities and to ensure that the repairs are accomplished in a manner which will correct the failure mode.

a. Cost for Retest

The cost for retest have been included in the initial fee. Thus, the retest would be carried out without supplementary costs. The retest load would be in line with the stringency factor used. For example: 35 percent stringency factor; Total Test Load = number vehicles to be inspected x 1.35. It is assumed that only one retest would be required.

5. Value of Warranty Repair Work Performed

Section 207 of the Clean Air Act mandates a new vehicle and engine emissions warranty which includes a general defects warranty in 207(a), a performance warranty in 207(b)* and an enforcement and recall provision in 207(c). 207(a) has generally been interpreted to require manufacturers to warrant vehicles or engines to be free from defects in materials and workmanship that will cause them to violate applicable regulations, including applicable emissions standards.

A list of applicable emissions control items, interpreted as included under this standard and, therefore, makes vehicle manufacturers liable for the failure of these emissions-related part is presented in Appendix I. It is assumed that these items could reasonable be expected to degrade the emissions performance of a failure of the vehicle. 207(b), which specifies a performance warranty generally provided for in 207(a), cannot be implemented at the Federal level until the administrator promulgates a correlatable short test on which the performance warranty can be based. When the EPA determines that a short test is available which is "reasonably capable of being correlated" with the official certification test, then manufacturers will be liable to correct vehicles which fail such a test regardless of whether any specific part defects have been identified.

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*Throughout this report, "performance warranty" means a warranty that a vehicle's emission will not exceed the certification emission standards for its useful life, as evidenced by a correlatable short test.

Manufacturers argue that the Clean Air Act Amendments of 1977 showed that Congress intended to limit the 207(b) performance warranty to "hang-on" components only (e.g., air pump, catalyst, EGR valve). Congress has diminished the scope of the 207(b) warranty to some extent and its interpretation needs clarification.

It is assumed that the 207(b) warranty presently only applies to "hang-on" components after 24,000 vehicle miles: before the 24,000 vehicle mile point has been reached, however, 207(b) applies to a broader range of emission-related components. This range is, as yet, undefined, since EPA has failed to promulgate a specific list; however, it is clear that Congress intended this list to be broader in application than the "hang-on" component definition.

Congress did not amend the scope of the 207(a) defects warranty; it still applies to a broader range of emissions-related components (as yet undefined on a Federal level) for the full useful life period of 50,000 miles. Warranty, however, has limits with respect to abuse, and neglect of improper maintenance. The repair or replacement of any emissions-related part otherwise eligible for warranty coverage shall be excluded from such warranty coverage if the vehicle engine, has been abused, neglected, or improperly maintained, and that such abuse, neglect or improper maintenance was the direct cause of the need for the repair or replacement of the part.

The State of California (Ref. 17) in 1977 completed a surveillance test program on 1975 to 1976 model-year vehicles. These vehicles were tested using:

- CVS-75 test used in new car certification
- Federal highway fuel economy test

- Loaded-mode test
- Acceleration/deceleration driving sequence EPA modal test
- Sealed housing evaporative determination (SHED) test

Only 9 percent of the vehicles failed because of a defective components. These defective components may not have been covered by warranty because of:

- lack of maintenance
- abuse of vehicle
- others.

It is, therefore, evident that the subject of warranty repair work performed requires further study and definition to form a basis for analysis.

For this study it was assumed that approximately 4 percent of the less than 24,000 miles vehicle had defect parts prior to testing and would require warranty parts replacement. The average cost of such a replacement would be approximately $35.*

E. INDEPENDENT PROGRAM VARIABLES

1. Enforcement

a. Program Enforcement Alternatives

This section will examine proposed enforcement mechanisms that could be adopted to compel vehicle owners to comply with requirements outlined in the South Carolina SIP. The analysis will address two enforcement alternatives related to light-duty vehicles, specifically, 1) withholding vehicle registration, and 2) change of ownership.

Vehicle Registration - The South Carolina Vehicle Registration System provides for a fully computerized and efficient data-handling system that continuously processes detailed information on owners (name, sex, age, driving history, etc.) and vehicles (make, model, year). This information is constantly updated and is readily available to governmental agencies directly concerned with I/M program requirements. These factors identify the vehicle registration system as a likely candidate for an emission test enforcement control point.

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*This data is based upon a California ARB communication.

The vehicle registration system could provide for an annual inspection process by making an emission test a necessary prerequisite for the successful completion of the registration process. Upon receipt of vehicle registration renewal application, the owner would be required to obtain a Certificate of Compliance from a Certified Emission Test Station within a specified period of time (e.g., 30 days). A condition of noncompliance would result if the vehicle owner:

- Ignores emission test requirements
- Fails to pass established emission test standards
- After failure of emission test, does not obtain the necessary repairs and retest.

Noncompliance would result in nonregistration of the vehicle and, in effect, deny the right to operate the vehicle.

b. Change of Ownership

As a prerequisite for transferring the title, the new owner would be required to supply a Certificate of Compliance demonstrating that the vehicle complies with established emission standards.

2. Repair Analyses and Consumer Protection

This section reviews major program components, needs, and problems associated with a comprehensive emission repair consumer protection effort. These requirements include:

- Designation of lead agency to assume overall consumer protection responsibility.
- Implementation of consumer protection programs and issues.
- Regional responsibility of consumer protection implementation.

a. Lead Agency Designation

Prior to I/M implementation, the South Carolina State Legislature should expand the administrative authority of the Consumer Affairs Office (CAO) to include a comprehensive emission repair consumer protection program. This would enpower the CAO to develop and establish procedures to implement warranty protection standards and guidelines requiring:

- The repair and/or replacement of emission control systems during the warranty period.
- That vehicle manufacturers produce durable, maintenance free emission control devices.
- Recall and field repair programs when justified by an unusual number of failed emission control devices.
- That replacement components are available and not inferior to the Original Equipment Manufacturer's (OEM) equipment.

The CAO could also institute procedures to review complaints that relate to emission control component failures and would cooperate and assist other departments associated with I/M programs that are germane to consumer protection. Finally, the CAO would institute certification/qualification criteria of service industry emission repair.

Additional responsibilities that relate to I/M program requirements and needs include the areas of:

- Education - assists in the development of consumer education programs.

- Hearings - conducts public hearings that involve emission repair rules and regulations.

- Promotion - promotes ethical standards of business conduct in the emission repair industry.

- Information - Advises the public, the Governor, and the Legislature on all matters that affect on-going I/M requirements.

- Representation - represents the consumer's interest before Federal and State Legislative hearings and executive commissions.

b. Implementation of Emission Repair Consumer Protection Program

The proposed emission repair consumer protection program may be summarized under the following categories:

- Warranty protection
- After-market parts program
- Modified parts program
- Recall/defects program
- Grievance and complaint procedures
- Certification criteria for repair facilities
- Repair cost ceilings
- Public information.

A brief description of the scope of the emission repair consumer protection program for each category follows:

Warranty Protection - The Motor Vehicle Emission Control Office (MVECO) should develop and establish regulations to ensure that vehicle owners are protected from abuses related to the 24-month, or 24,000 miles, warranty provision set forth in the Emission Control System Performance Warranty of Section 207(b) of the Clean Air Act 1977 Amendments. The Emission Performance Warranty further requires the automobile manufacturer to warrant the catalytic converter, thermal reactor or other components installed on or in a vehicle for the sole or primary purpose of reducing emissions for a period of 50,000 miles or 5 years, whichever comes first. Appendix I list emissions-related equipment which should be identified within this warranty coverage.

The manufacturer must bear the cost of repair of any properly maintained and operated vehicle which fails an EPA-established emissions test within 24-month/24,000-mile or 5-year/50,000-mile, as appropriate.

After-Market Parts Program - This program is separate and distinct, and should be reviewed in light of the effect of such parts on emissions control. The replacement parts manufacturer should be responsible for the original equipment performance requirements to ensure a continuity in emissions control.

Modified Parts Program - Provisions should be made to ensure that vehicle owners do not install equipment such as bleeder valves which may have a decided effect on emissions. Such a program may require that equipment be certified by the state as not having a significant effect on emissions prior to the sale of such products within the state.

Recall and Defects Control - Consideration is required with regard to the follow-through of recall and original manufacturer's defective parts programs as to how each problem relates to test site operation and follow-through assurance that the dealerships respond to the installation requirements of related repairs. These do have a decided effect on emissions in many cases.

Consumer Complaint Management - In the initial phases of the I/M program, some complaints may emanate as a result of inspection procedures and personnel, but it is more likely that the majority of complaints will be in relation to repair actions. It is important that these complaints are processed rapidly and acted upon within a reasonable period of time. If justified complaints are not resolved to the satisfaction of the consumer, adverse public reaction to the I/M program concepts may result.

The CAO could provide efficient mechanisms to process complaints concerning warranty protection, overcharging and unnecessary repairs by individual garages, as well as complaints about the program in general. These mechanisms would include: 1) a statewide information and referral system available through a toll free number, and 2) complaint forms available at each inspection facility. Once the complaint is received through other processes, a consumer representative would attempt to resolve the problem over the telephone. If the complaint is not resolved to the satisfaction of both parties, the consumer representative would refer the matter to the Motor Vehicle Emission Control Office for further arbitration.

In addition to the complaint service, the Automotive Division of the CAO would maintain permanent records of consumer complaints on each repair facility. If too many complaints about any one facility are received, the CAO could investigate, and revoke the license of the garage if the claims were justified.

Certification of Repair Facilities - Ultimately, an I/M program can accomplish emission reduction only if it increases the frequency and quality of vehicle maintenance than would have occurred voluntarily. Clearly, the quality of the maintenance performed in response to emission inspection failure will have an important impact on I/M program effectiveness and cost. The performance of service garages participating in emission repair work has been evaluated from two viewpoints. One viewpoint has considered the capability of repair agencies to perform emission-related work; and the second, the extent of unwarranted repair, and the resultant unnecessary cost burden.

A recent California study has examined the ability of repair facilities to follow Motor Vehicle Inspection Program (MVIP) repair procedures for dealerships, service stations, and independent garages. Table 4-22 presents data indicating that of those repair facilities surveyed, approximately 26 percent and 56 percent did not follow established repair procedures for idle and loaded tests, respectively. Also, it was found that when repaired vehicles were returned for reinspection, approximately 16 percent (idle) and 29 percent (loaded) failed emission retest (Table 4-23). This suggests that there is need for close supervision of emission repair facilities.

In view of the above information, the Motor Vehicle Emission Control Office would establish stringent certification and qualification criteria for emission repair garages. Repair garages approved for emission repair work must:

- Employ at least one mechanic certified to perform emission repair work.
- Own or lease analyzers capable of accurately measuring HC and CO levels.
- Provide incentives for mechanic retraining every 1 to 2 years.

In addition to the above qualifications, each garage should serve a minimum probationary period of at least 1 year. This would include close supervision of the repair operation using correlation vehicles and referee stations to check the adequacy of repair maintenance.

Repair Cost Ceilings - Another responsibility of the Motor Vehicle Emission Control Office includes the regulation of emission repair costs. This would be accomplished by fixing maximum price ceilings on all emission repair work. Table 4-1 examined the effect of reducing the maximum repair cost ceiling on percentage of failures repaired, average repair cost, average fuel economy, and total emission reduction. For example, as the maximum repair cost is reduced from $150 to $100 ($10 increments) there are no observed reductions.

Table 4-22. ABILITY OF REPAIR FACILITIES TO FOLLOW THE MVIP REPAIR PROCEDURES

	IDLE REGIME		LOADED REGIME		BOTH REGIMES	
	Total Repaired	Did Not Follow Repair Procedure	Total Repaired	Did Not Follow Repair Procedure	Total Repaired	Did Not Follow Repair Procedure
Dealerships	34	7 (21%)	83	51 (61%)	117	58 (50%)
Service Stations	24	9 (38%)	117	57 (49%)	141	66 (47%)
Independents	87	22 (25%)	96	58 (60%)	183	80 (44%)
ALL	145	38 (26%)	296	166 (56%)	441	204 (46%)

Table 4-23. REPAIRED VEHICLES WHICH FAILED REINSPECTION

IDLE REGIME	TOTAL REPAIRED	FAILED FIRST REINSPECTION	WAIVED	FAILED FIRST REINSPECTION, EXCLUDING WAIVED VEHICLES
Dealerships	34	0 (0%)	0 (0%)	0 (0%)
Service Station	24	6 (25%)	3 (13%)	3 (13%)
Independents	87	17 (20%)	8 (9%)	9 (10%)
ALL	145	23 (16%)	11 (8%)	12 (8%)

LOADED REGIME	TOTAL REPAIRED	FAILED FIRST REINSPECTION	WAIVED	FAILED FIRST REINSPECTION, EXCLUDING WAIVER VEHICLES
Dealerships	83	20 (24%)	10 (12%)	10 (12%)
Service Stations	117	36 (31%)	20 (17%)	16 (14%)
Independents	96	30 (31%)	13 (14%)	17 (15%)
ALL	296	86 (29%)	43 (15%)	43 (15%)

However, if the maximum repair cost is lowered below $100 (baseline), there are 2 percent to 4 percent reductions in every category. This seems to indicate that there is a compromise point between what the public is willing to pay (repair cost ceiling) and the desired level of emission reduction, fuel economy, and average repair cost.

Once the maximum repair cost ceiling is established, vehicles with consumer repair work exceeding the cost ceiling would be exempt. This avoids placing undue economic hardships on owners. The cost of exempting certain vehicles from having emissions-related repair work performed is the reduction in the overall effectiveness of the program. Given the relatively small percentage of major emissions-related repair work, however, it would appear that little decrease in overall emissions reduction would result from the exemption of some vehicles. This is based upon the fact that in Oregon and Arizona only 2 percent of the tested vehicles cost more than $100 to repair. In New Jersey, the figure was 5.6 percent. It would appear, therefore, that the gains in terms of public acceptance would tend to outweigh any decrease in emission reduction resulting from the waiving of repair requirements for certain vehicles.

Recent studies have shown that the average repair cost is estimated to be within a range of $26 to $34 for idle/loaded test regimes, prior to year 1975 (Table 4-24a). In addition, there is a $2 to $8 overcharge that is directly attributable to unnecessary or unwarranted repair work. This problem can be remedied only if the inspection station provides accurate diagnostic and price information for the consumer.

All repair costs in Table 4-24b were result from various studies. The recent Arizona I/M experience revealed that the average cost of repairs to failed vehicles was $23.02 during 1977. These costs ranged from zero for warranty repairs to cover $600 for an engine overhaul. Table 4-24 presents the average cost of repairs for various model year groupings versus facilities performing the repairs. The analysis of total repair costs indicated that 50 percent of the vehicles were repaired for less than $11.25 (Ref. 21).

Table 4-24a. AVERAGE REPAIR COSTS - FAILED VEHICLES[a]

	IDLE TOTAL	IDLE OVERCHARGE	LOADED MODE TOTAL	LOADED MODE OVERCHARGE	= DEFINE
California Study (Ref. 2)	$21	$2	$23	$5	35%
Northrop (Ref. 3)	$34	-	$30	-	50%
EPA (Ref. 4)	$26	$8	$28	$7	50%
Olson (Ref. 5)	$26	-	-	-	50%

[a] Unadjusted dollar costs in various years.

Table 4-24b. ARIZONA - 1977 REPORT (REF. 21)

TYPE FACILITY	1964-1967	1968-1977	1964-1977
Franchised dealers	$41.25	$26.82	$27.97
Service stations	23.06	19.81	21.14
Merchandisers	15.53	20.29	19.43
Tune-up specialists	36.19	22.86	24.72
Independent garages	21.33	27.46	26.79
"Do-It-Yourselfers"	14.27	20.61	19.08

In turn, the consumer can go to an approved repair facility and request specific repairs, fully confident that an established price will not be exceeded.

Public Information Program - Many questions raised by I/M implementation can be properly addressed through a well-designed and comprehensive public information program. It can help to eliminate adverse public criticism by stressing the purpose, objectives, benefits, and operation of I/M. Emphasizing the checks and balances (e.g., quality assurance) designed into the I/M program and health benefits from emission reductions will alleviate many problems associated with the implementation procedure.

A public information program can address other benefits to the vehicle owner. Improvements on fuel economy, vehicle performance and longevity are important to vehicle owners. Control of vehicles that emit annoying quantities of smoke, and assurances that I/M requirements will extend to all vehicles are important points to stress.

This is accomplished by effective use of advertising techniques that utilize the mass communication media (e.g.; radio, television, newspapers, etc.), information centers, education programs, citizen group contacts, etc. In the early stages of I/M implementation, initial program information should include:

- Explanations that outline control procedures and derived benefits from automotive emission controls.

- Explanations of what automotive equipment requires inspection.

- Identification of the most common causes for emissions failure.

Supplemental information is required after the public has accepted the need to understand the concepts of I/M. This additional information includes:

- The location of test facilities.

- Instructions and fee requirements.

- Explanation of retest requirements and conditions.

- Importance for allowing time for repair, and retest, or considerations for waiver.

- Explanation of complaint referral system.

c. District Responsibility of Consumer Protection Implementation

The responsibility of implementing an emission control consumer protection program on a regional basis belongs to the "Emission Control Investigative Unit" (ECIU)--the investigative arm of the Vehicle Inspection Office. The primary function of the ECIU is to prevent fraudulent automotive emission repair practices on vehicles identified as having failed to meet emission standards. These fraudulent emission repair practices include overcharging and performing unnecessary or unwarranted repair work. Under I/M program requirements, the automotive emission repair dealer must:

- Supply the consumer with a written estimate before any emission repair is performed. The estimate is calculated by using state established emission repair prices.

- Obtain authorization for any expense in excess of the original estimate, and not to exceed the maximum repair price ceiling.

- Provide the consumer with an itemized invoice clearly showing all labor and parts supplied. This fully informs the consumer of the cost and nature of the emission repairs performed on the vehicle.

- Refrain from false advertising, misleading statements, or promises intended to induce an uninformed consumer to agree to unnecessary repairs.

The ECIU accepts and processes complaints that involve infractions of any of the above four regulations. Consumer representatives of the CAO operate a statewide information and referral network through which consumers may register their complaints. An attempt is made by the consumer representative to satisfy the complaint by contacting the emission repair dealer. If there is no agreement, the complaint is referred to a field investigator of the ECIU. The responsible investigator will meet with the consumer and repair dealer and, in some instances, examine the repair work to ensure that provisions of the law are satisfied. Under unusual circumstances, investigators may at their discretion use a specially outfitted surveillance vehicle to check the integrity of emission repair work. If there is sufficient evidence of consumer fraud, the matter will be turned over to the CAO for further investigation, and possibly prosecution.

The ECIU will also have the responsibility of testing and licensing individual facilities as official emission repair stations. When an automotive repair facility employs an individual trained in emission control equipment repair, and owns or leases approved emission HC/CO analyzers, the facility may apply for a license as a State Approved Emission Repair Facility. Field investigators will make periodic checks of all licensed stations to inspect all phases of emission repair work. Any irregularities in the operation, quality of repair work, pricing, etc., may result in revocation of the license.

In cases that involve flagrant violations of consumer rights, the ECIU may request that the CAO begin proceedings against certain repair facilities. It should be anticipated that many cases would be settled by decree or voluntary compliance. However, when there is evidence of serious violation, cease and desist orders should be sought. The CAO would decide whether a formal complaint is required, enter into a consent settlement and, if necessary, try the case before a hearing examiner. Where consumer abuse is localized, the CAO would establish a liaison with and refer the matter to municipal or county authorities for possible criminal investigation.

3. Quality Assurance

a. Inspection and Maintenance Equipment Standards

The equipment standards are classified and discussed according to the two following categories: sampling system considerations and selection, and gas analyzer considerations and selection. The sampling system and gas analyzer considerations sections discuss the various technical problems and solutions associated with the analysis of vehicle exhaust gas emissions. The selection sections discuss the basic requirements for the equipment to adequately perform the analysis.

Included in this section is a table giving relevant information concerning a small sample of gas analyzer systems currently available and suitable for an I/M program. Within this information are specifications defining the ambient conditions necessary for valid emission analysis.

Sampling System Considerations - Exhaust gases are extremely complex mixtures of HC, CO_2, CO, NO_x, aldehydes, particulates, water, nitrogen, oxygen, hydrogen, and many other compounds. To accurately measure any single pollutant, the application of proper gas sampling techniques and careful sample handling treatment prior to instrument analysis are required. The basic consideration must be to obtain a sample of exhaust gas which is completely representative of the vehicle exhaust for the operating condition of interest.

It becomes necessary to selectively remove those materials and compounds which may affect the absolute measurement of the subject pollutant without changing the concentration or characteristics of that pollutant. In a practical sense, this generally means reducing the water vapor level in exhaust gases and filtering out the particulates before passing the gas sample through a measuring instrument. Additionally, the sample handling system must also provide for the periodic inputting of zero and span check gases and calibration gases.

Sampling System Selection - The sampling system may consist of a tail pipe probe, sample line, vapor condensor, particulate filter(s), sample pump and appropriate valves for the check and calibration cycles and for purging the system. In the definition of a sampling system, the following need to be considered:

- Avoidance of materials that are subject to corrosion, deterioration and HC hang-ups.
- Adequate flow rates for fast system response.
- Rugged construction of sample lines and probes to withstand heavy usage.
- Filtering system of adequate capacity and serviceability.
- Adequate provisions for water removal.

Gas Analyzer Considerations - The heart of any automobile exhaust emission test system is the instrument component required to measure the levels of pollutants. Depending on the type of test being conducted, the analyzers will vary from relatively simple and inexpensive to highly sophisticated versions.

A large number of sophisticated exhaust gas analysis systems have been assembled and used in research programs and in the certification and quality audit of new cars to evaluate their compliance with state and Federal standards. At the other end of the spectrum, some relatively simple analyzers are being used by garage mechanics and tune-up technicians to assist in adjusting engine operating parameters during maintenance. The instrument system required in a mandatory inspection program probably lies somewhere between these extremes.

Typical Gas Analyzer Selection - For I/M applications, prior to the selection of the exhaust emission analyzers, the emission inspection limits should be reviewed to ensure that all necessary ranges are considered. With the introduction of catalytic reactors and other refinements on new vehicles to comply with emissions standards, engineering estimates should be used to predict the measurement levels anticipated in the near future. Other factors to be considered in defining instrument specifications include accuracy, speed of response, stability, effect of interference gases, ease of operation, and maintenance.

Carbon Monoxide - The most commonly used method for CO measurement in exhaust analysis is the nondispersive infrared (NDIR) technique. These instruments are based on the principle that the infrared absorption spectrum of the measured gas is sufficiently unique as compared to any other exhaust component gas, and that measurement of infrared energy absorption is proportional to the concentration of the component of interest in the presence of other gases.

The sensitivity of the NDIR instrument is proportional to the physical length of the sample cell. CO monitors have been built for ambient air monitoring which can detect CO in the 1 ppm range. The sensitivity requirement for exhaust CO analysis is much less severe because the concentrations in exhaust gases are orders of magnitude higher than in the atmosphere.

On the high end, CO is occasionally observed in the exhaust gases of uncontrolled (pre-1968 model) cars in concentrations above 10 percent. On the low end of the range, some properly tuned and adjusted engines on controlled cars will produce CO concentrations lower than 0.1 percent during idle and cruise modes of operation. Thus, the CO instrument should provide accurate readouts over the range of 0 to 10 percent. A preliminary conclusion is that the CO analyzer required for the mandatory inspection program will require two or more gas concentration ranges from 1 to 10 percent.

Hydrocarbons - The analysis of HC in automotive exhaust gas is complicated by several factors. HC are a complex mixture and their concentrations vary over an exceptionally wide range. The NDIR technology may also be used for HC measurements or, as in current Federal mass testing, the Flame Ionization Detector (FID) is used.

NDIR analyzers using detectors sensitized with N-hexane had been the standard for measurement through 1971. FTP for 1972 and subsequent years specified use of FID due to the higher sensitivity required for dilute exhaust gas measurement. Neither instrument method is clearly superior and either method can be incorporated into a mandatory inspection program. Presently, the NDIR analyzer has been most successfully adapted to a relatively low-cost rugged analyzer for inspection use, but the characteristics of FID analyzers need to be examined also.

FID instruments are significantly different from NDIR analyzers in that they measure the total HC present in a sample of exhaust gas. The FID method also can be electronically switched over a wide concentration range making only one instrument necessary in those test modes which require high dynamic range. The measurement of total HC is, however, not necessarily desirable for two reasons:

- Methane contributes to the response in the FID instrument; but, being a nonreactive component, it is debatable whether it should be included in HC measurement.
- Since the NDIR method is the only one used at the repair shop level, and the NDIR does not respond to methane, correlation between the inspection station and repair shop would be questionable if the FID were used for inspection.

Another important consideration in the selection of the instrumention is the wide range of values required to measure HC concentration in the various modes of vehicle operation. During vehicle testing, HC concentrations of a few thousand ppm are commonly observed and, occasionally, values in excess of 10,000 ppm are observed. Conversely, observed values of less than 50 ppm are common in the exhaust of well adjusted 1972 to 1974 emission controlled cars operating in steady-state modes; even lower values are observed with 1975 and later vehicles.

For the I/M exhaust emission program, the NDIR analyzer is probably the best choice because it is reasonably stable and trouble free. Calibrations and maintenance procedures are well defined and their effectiveness well established. Many thousands of these instruments, produced by several major manufacturers, are being used very successfully in automotive exhaust emissions analysis.

For the final analyses, the selection of HC instrumentation depends on the degree of measurement accuracy and ranges required based on an evaluation of the exhaust emissions inspections standards established by the state. Table 4-3 provided information concerning a small sample of exhaust emission analyzers suitable for use in an I/M program.

b. Inspection System Quality Assurance Plan

The Quality Assurance Plan is classified according to the four following categories: daily operational checks and adjustments, scheduled preventive maintenance, major maintenance and repair, and periodic instrument calibration checks. The first two categories are conducted on a routine, as-required basis and are performed during normal working hours by inspection facility personnel. Major maintenance should be available on an on-call basis by fully trained service personnel supplied by the appropriate instrument manufacturing company. The major maintenance service personnel would repair and overhaul major equipment and have available a complete stock of spare parts and major equipment replacement units. Periodic instrument calibration checks would be performed by qualified state inspectors dispatched from a central state-operated facility. The state inspectors would conduct the calibration checks using a fully equipped mobile test unit.

Daily Operational Checks and Adjustments - Daily operational checks of the vehicle inspection system would be performed by inspection facility personnel prior to opening for business. The daily operational checks schedule is shown in Table 4-25.

Table 4-25. DAILY OPERATIONAL CHECKS AND ADJUSTMENTS

CHECK	ADJUSTMENT	MAINTENANCE
NDIR Gas Analyzer	Zero and Span. One/shift by the supervising inspector and one per six tests by inspection personnel	None
Sample Handling	Temperature, flow and pressure check once/shift by inspection personnel	Replace filters or damaged sample probe as required
Working gases	Turn on gas and adjust output pressure if necessary	Check cylinder gauge pressure and replace gas cylinder as required

The NDIR CO/HC analyzers require initial zero and span check to verify that the test lane operational status is according to specifications. The NDIR gas analyzers would be zeroed and spanned manually at the beginning of each work shift by the supervising inspector or surrogate. For the remainder of the shift, the inspector should compensate for minor zero or span shifts once every six tests. Repeated zero and span drift error will require that the analyzer receive first echelon maintenance.

At the beginning of each shift, the temperature of the water bath would be checked and adjusted as required. The pressure and flow of the exhaust sampling system would be checked and adjusted to specified values by the supervising inspector or other inspection personnel. Cylinder pressure of the working gases (zero and span for the NDIR analyzer) would be checked each shift and new cylinders will be installed by the facility personnel if the pressure drops below 100 PSI.

Scheduled Preventive Maintenance - Preventive maintenance of the vehicle inspection system would be accomplished on a scheduled basis and integrated into the daily operational checks by the inspection facility supervising inspector.

Preventive maintenance for the sampling system would be performed at the beginning of each shift. The tail pipe sample probe and sample line would be checked for damage and restricted sample flow. The water trap and aspirator would be checked for deposits and cleaned as required. The exhaust gas filter would be checked and replaced as required.

The preventive maintenance for the analyzers would be performed periodically as specified by the instrument manufacturer.

First Echelon Repair - Daily operational checks and adjustments or periodic calibration and preventive maintenance activities may reveal a functional problem or a defective component. The inspection facility personnel would perform the required maintenance when the problem can be readily isolated down to available spare parts. Two categories of spares would be maintained: (a) operating disposable spares including filters, and (b) field replaceable spares including indicator lights, fuses, and sample probes. All repair activities would be in accordance with equipment manufacturer's repair and adjustment procedures.

Major Maintenance - Those system failures which cannot be corrected by inspection facility personnel due to problem complexity, spare parts, or troubleshooting instrumentation, would be referred to the appropriate manufacturing company responsible for major maintenance. The inspection facility supervising inspector would inform the manufacturer of the problem, provide a detailed description of the malfunction and describe the impact on vehicle testing. Based on these descriptions, the manufacturer would dispatch the skilled service personnel and required resources to accomplish the field repairs.

To perform the vehicle inspection systems repair and to limit system downtime, components for the systems would be maintained by the manufacturer. When a system failure occurs and the failed component can be promptly identified by the vehicle inspection facility, the replacement component would be dispatched from the manufacturer so that the equipment can be repaired and recalibrated.

Periodic Calibration Checks - Periodic calibration checks would be performed at 90-day intervals. These periodic calibration checks would be performed by qualified state inspectors. The state inspectors would operate out of a mobile test unit dispatched from a centrally located state facility. The mobile test unit would be equipped with an NDIR gas analyzer, remote tachometer, !1 percent calibration gases, tachometer calibrator, field-type diagnostic equipment and field replaceable spare parts. For customer and facility owner convenience, the calibration checks would be prearranged to allow for scheduled downtime. The expected downtime involved for each facility calibration check is one hour, providing that no problems are encountered. The periodic calibration check schedule is shown in Figure 4-5.

The remote tachometer calibration check would be performed using the tachometer calibrator, and necessary adjustments and repairs would be made per manufacturer's specifications.

The NDIR gas analyzer would receive a 5-point calibration test with !1 percent certified calibration gases; any necessary adjustments and maintenance would be made per manufacturer's specifications.

A correlation test would then be performed using the state mobile unit as the test vehicle. The mobile unit would receive one emission test using the facility instrumentation and one emission test using the state-owned instrumentation located on board the mobile test unit. The emission test results would then be compared for accuracy.

If the calibration check and correlation test results fall within the specified range, the inspection facility would receive a 90-day certification. If the inspection station fails the calibration check and/or the correlation test, it would not be recertified and, therefore, would not be able to perform emission testing. It would then be the responsibility of the facility to have the equipment corrected and to contact the Motor Vehicle Division (MVD) to be rescheduled for calibration testing.

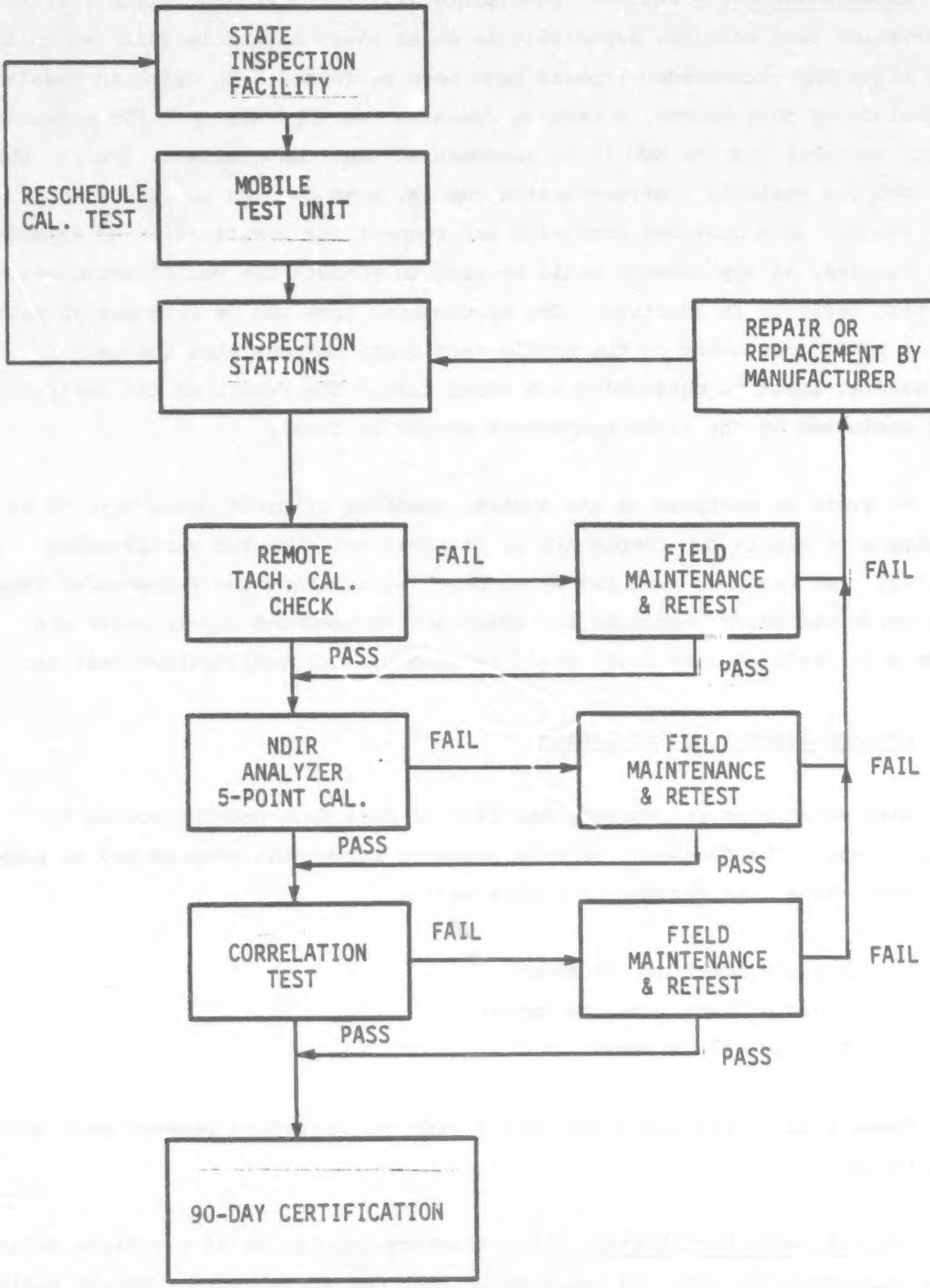

STATE INSPECTION FACILITY
MOBILE TEST UNIT
RESCHEDULE CAL. TEST
INSPECTION STATIONS
REPAIR OR REPLACEMENT BY MANUFACTURER
REMOTE TACH. CAL. CHECK
FAIL
FIELD MAINTENANCE & RETEST
FAIL
PASS
PASS
NDIR ANALYZER 5-POINT CAL.
FAIL
FIELD MAINTENANCE & RETEST
FAIL
PASS
PASS
CORRELATION TEST
FAIL
FIELD MAINTENANCE & RETEST
FAIL
PASS
PASS
90-DAY CERTIFICATION

Figure 4-5. STATION CERTIFICATION PROCEDURE

Referee Vehicle - Customer complaints will arise regarding the reliability of emission test results, especially in cases where a vehicle fails an emission test after the recommended repairs have been performed. In order to resolve complaints of this nature, a referee operation must be set up. For convenience to the customer and the MVD it is recommended that the mobile test units which are used for periodic instrumentation checks, also be used as referee operation. Upon receipt of a customer complaint and request for verification of emission test results, an appointment would be made to conduct the verification test at the test facility in question. The appointment time can be arranged in such a way as to be convenient to the mobile test unit, perhaps when the unit is in the general location performing its usual task. The result of the verification test conducted by the state inspectors should be final.

To avoid an overload on the system, specific criteria would have to be developed to single out complaints of possible validity for verification testing. For example, vehicles which have failed after the recommended repairs were performed and/or vehicles for which the recommended repair costs are above some predetermined level would be eligible for verification testing.

4. Data Management System Design

Data management encompasses the flow of data from primary source to ultimate use. The mandatory vehicle emission inspection program may be broken down into three data management subsystems:

- Vehicle owner notification
- Vehicle inspection and repair
- Program effectiveness

These will be discussed separately with the interface between each pair identified.

Vehicle Owner Notification - Satisfactory completion of a vehicle emissions inspection would be required prior to initial and annual motor vehicle registration. Annual registration would be accomplished on a month-to-month basis.

Notification of registration renewal would be supplied to the owner approximately 2 months prior to the final date for renewal. This would provide sufficient time for the owner to have his vehicle inspected, to have any required repairs completed, and to be retested. The most expedient and least costly way to notify the owner of the inspection requirement would be as part of the automobile registration renewal packet.

Two items of information would be required for inclusion in this packet:

- An explanation of the requirement and instructions for accomplishment of the inspection.
- A Vehicle Identification (VID) card to be used by the inspection facility to identify the vehicle and applicable exhaust emission data; e.g., emission control device(s) installed, appropriate emission levels, etc.

Vehicle Identification Card (VID) - A VID card would be provided which contains sufficient information to identify the vehicle to be inspected. This fixed information would be recorded on the inspection report form along with variable information such as odometer reading and inspection number. The VID card must be presented in legible condition, along with the automobile registration renewal card, to the inspection facility personnel prior to inspection. Lost VID cards would be duplicated at the facility office. In no case would a vehicle be tested without this documentation. The two documents and the vehicle would be compared for accuracy and for missing data.

At the beginning of the inspection program, it is known that some of the data required for accomplishing the inspection will not be available from the DMV. Missing data may include:

- Vehicle weight class
- Emission control systems installed
- Number of cylinders
- Applicable emissions standard code

These would be determined at the initial inspection and marked on the VID card. It could also be noted on the automobile registration card retained by the owner and on the portion retained by the MVD so that their files can be updated.

It would be the vehicle owner's responsibility to safeguard this VID card for use at subsequent vehicle inspections (e.g.; next annual registration, installation of a different model-year engine or an engine with a different number of cylinders, change of ownership, etc.). Should any of the information on the card require a change, it would be necessary for the vehicle owner to go to a designated site to obtain an updated card. Should the owner lose or destroy his card, he would be required to pay a fee for its replacement. This will entail the transcript of information from his automobile registration card and perhaps a physical inspection of the vehicle if data are missing.

Safeguards Against Fraud - It is reasonable to believe that some persons might try to beat the system by altering the information on the VID card to put the vehicle in a less stringent emission standards category and/or change the emissions control system requirement code. This can be overcome by using a card on which is imprinted the state insignia and by using special codes for identifying applicable standards and emissions control systems required.

Use in Identifying Retests - It would be necessary for a failed vehicle to return to the inspection facility at which it failed for a retest after repair. This would ensure that corresponding inspection and repair data are collected and greatly simplify data handling. Proper forewarning should reduce any inconvenience to the motorist.

Other persons might also use the inspection system as a low-cost diagnostic center whenever they suspected a problem with their vehicle. In one sense this is good, if a high polluting vehicle is detected and repaired voluntarily, but this places an unnecessary burden on the system.

Keeping track of the number of inspections is important, and it may become necessary to charge an additional fee for retests above some basic quantity, to discourage inefficient or ineffective repairs.

An effective method of accomplishing all of these safeguards would be to use a stamping device, much like a timeclock, to imprint the VID card with the facility number, date and time of an inspection. It would then be easy for the inspector to determine whether the vehicle was in for a retest, since only a short period (less than 2 months) would have elapsed since the last stamped test, and if he were at the correct facility for a retest. Approximately 12 of these imprints could be placed along the 3-1/4-inch edge of the VID card so the same card could be used through several years of inspections and retests. A replacement fee would discourage the vehicle owner from destroying his card to avoid paying a retest fee, or having to return to the facility at which his vehicle failed. Otherwise, it might also become necessary to imprint the back side of the automobile registration card as a double precaution since this would also be checked each time the vehicle was submitted for a test.

The alternative is to rely on the motorist to tell the inspector whether he is in for a retest or not. The driver, who would not necessarily be the owner, may honestly not know.

Vehicle Inspection and Repair - The data management responsibilities at the inspection facility would include the checking of registration documents to establish which emission standards are to be applied, checking the repair summary for completeness (if a retest, as noted by a recent date on the VID card) and checking certificates of retrofit installation (if required). If a retest, a copy of the previous inspection report form would be pulled from a Retest File for comparison.

Additional responsibilities would include the control of the information flow through the inspection process, the distribution of copies of the inspection reports depending on the inspection results, and the correlation of repair data with retest data. As an example, the flow of this data is shown in Figure 4-6. All hard-copy data would be retained at the facility for a period of at least 18 months.

Inspection Report Forms - The Inspection Report Form, Figure 4-7 would be completed in the following way. The information to be recorded from the VID

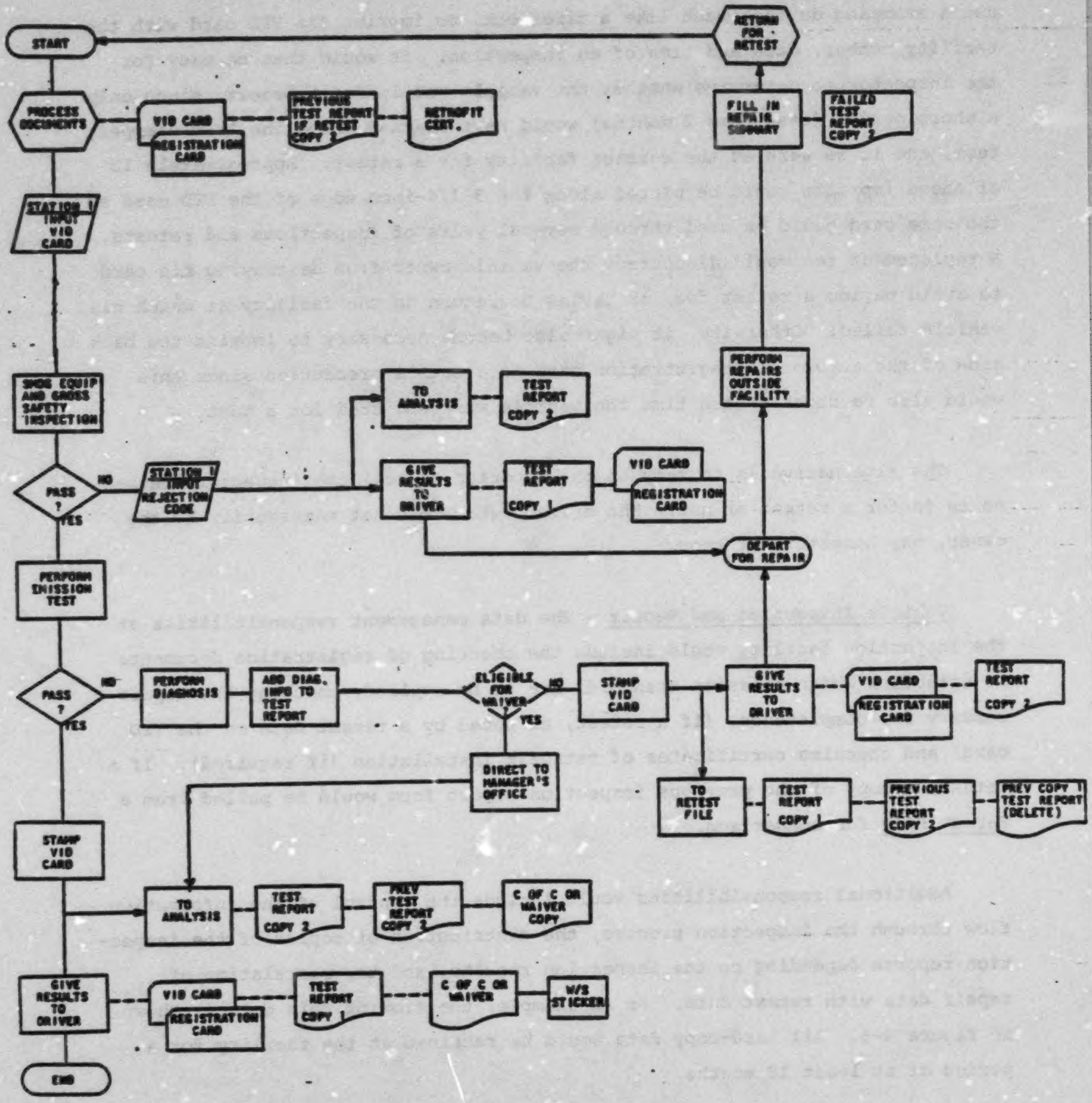

START
RETURN FOR RETEST
PROCESS DOCUMENTS
VID CARD
REGISTRATION CARD
PREVIOUS TEST REPORT IF RETEST COPY 2
RETROFIT CERT.
FILL IN REPAIR SUMMARY
FAILED TEST REPORT COPY 2
STATION 1 INPUT VID CARD
PERFORM REPAIRS OUTSIDE FACILITY
SHOG EQUIP AND GROSS SAFETY INSPECTION
TO ANALYSIS
TEST REPORT COPY 2
PASS ?
NO
YES
STATION 1 INPUT REJECTION CODE
GIVE RESULTS TO DRIVER
TEST REPORT COPY 1
VID CARD
REGISTRATION CARD
DEPART FOR REPAIR
PERFORM EMISSION TEST
PASS ?
NO
YES
PERFORM DIAGNOSIS
ADD DIAG. INFO TO TEST REPORT
ELIGIBLE FOR WAIVER ?
NO
YES
STAMP VID CARD
GIVE RESULTS TO DRIVER
VID CARD
REGISTRATION CARD
TEST REPORT COPY 2
DIRECT TO MANAGER'S OFFICE
TO RETEST FILE
TEST REPORT COPY 1
PREVIOUS TEST REPORT COPY 2
PREV COPY 1 TEST REPORT (DELETE)
STAMP VID CARD
TO ANALYSIS
TEST REPORT COPY 2
PREV TEST REPORT COPY 2
C OF C OR WAIVER COPY
GIVE RESULTS TO DRIVER
VID CARD
REGISTRATION CARD
TEST REPORT COPY 1
C OF C OR WAIVER
W/S STICKER
END

Figure 4-6
EXAMPLE OF TEST FACILITY DATA FLOW

VEHICLE INSPECTION REPORT

INSPECTION DATE ______________________

FACILITY NO. __________ LANE NO. __________

LICENSE NO. __________ YEAR ________ MAKE __________ MODEL __________

WEIGHT CLASS __________ CYL ________ SMOG __________ ODOMETER __________

FIRST TEST ☐

RETEST NO. __ ☐

TEST RESULTS:

		IDLE	2,500 RPM
HC, PPM	STD.		
	ACTUAL		
CO, %	STD.		
	ACTUAL		

☐ FAILED VISUAL INSPECTION

DECISION: ☐ PASS ☐ FAILED THOSE MODES DESIGNATED BY F

DIAGNOSTIC INFORMATION:

SEE REPAIR PROCEDURE NO. ____

MEASURED PARAMETERS AND DIAGNOSTIC MESSAGES

____

REMARKS ______________________________________

____

____

INSP. NO. __________ INSP. SIGN. ______________________

Figure 4-7. EXAMPLE OF INSPECTION PROGRAM REPORT FORMAT

card and visual inspection would include the year, make, model, number of cylinders, and smog code. Other information to be recorded would include license number, weight code, odometer reading, facility code and test number.

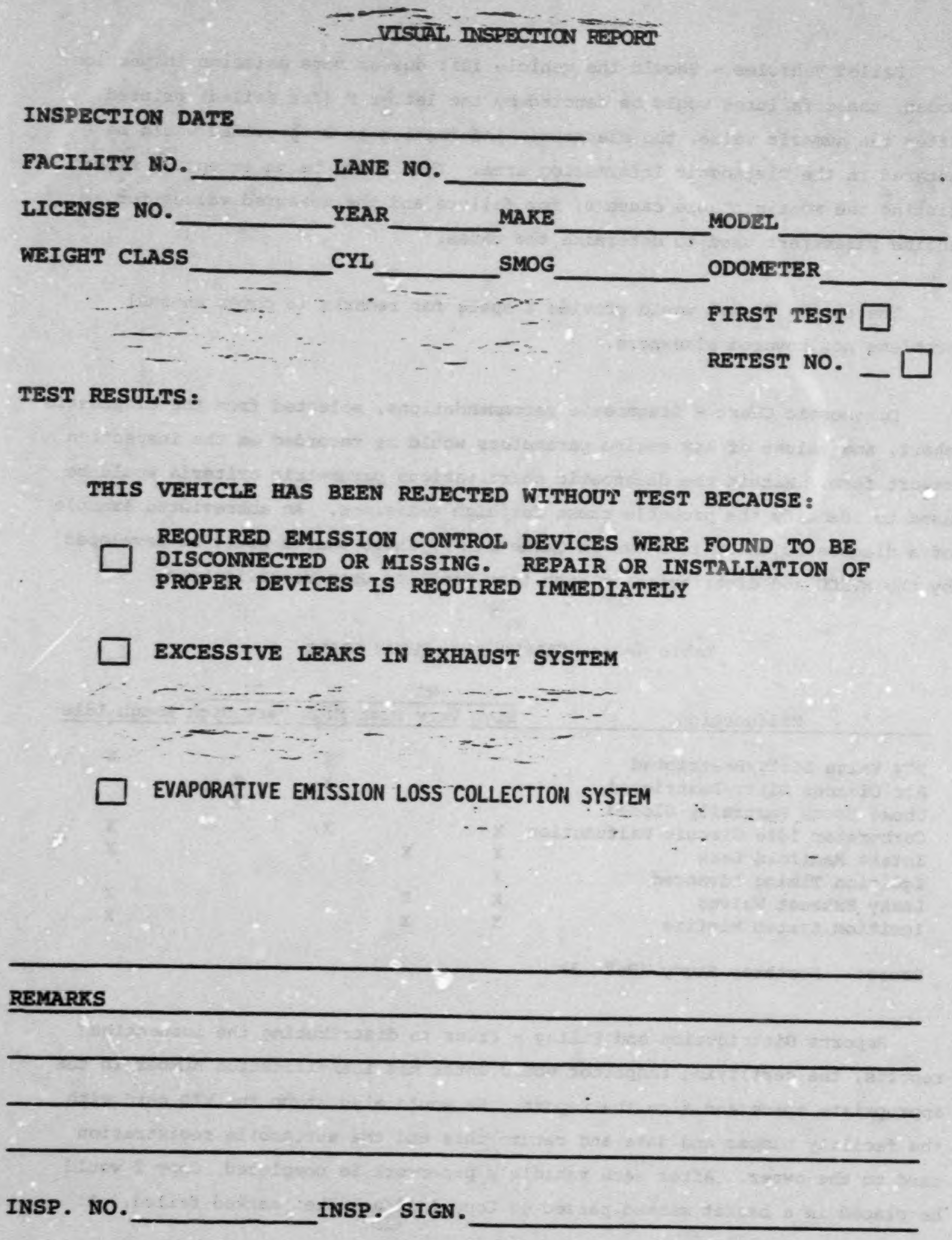
Proper installation of the original equipment control device(s) would be visually verified by the inspector. Other visual inspections will include checking the exhaust system and inspecting for excessive fluid leaks.

The results of the visual inspection would be recorded on the vehicle inspection report.

Visual Inspection Report Form - In the event that a vehicle fails the visual inspection, the Visual Inspection Report form, Figure 4-8, would be completed. Vehicles with original equipment control devices improperly installed would be rejected without emission testing. Other reasons for rejecting a vehicle prior to emission testing are exhaust system leaks and excessive fluid leaks which could effect emission test results. One additional reason for rejection after the vehicle is in place for emission testing is excessive sample dilution due to a faulty exhaust system not detected visually.

Emission Testing - When it is determined that a vehicle is testable, the emission test would be performed. Measured values would be recorded on the Inspection Report form, Figure 4-7, and compared to the proper emission standards. Based on this comparison, inspection personnel would make a pass/fail decision. In the case of a failed vehicle, inspection personnel would select proper diagnostic recommendations from the diagnostic chart and record them on the inspection report form. Further diagnostic information derived from visual inspections would also be recorded on the inspection report form.

Certification Forms - When the inspected vehicle's emission levels are less than the established standards, and no repair is required, a Certificate of Compliance would be issued. A copy of the Vehicle Inspection Report would be given to the vehicle owner for his information. This may be of value to his mechanic at the time of his regular maintenance especially for those vehicles that passed marginally.



VISUAL INSPECTION REPORT

INSPECTION DATE ____________________

FACILITY NO. ________ LANE NO. ________

LICENSE NO. ________ YEAR ________ MAKE ________ MODEL ________

WEIGHT CLASS ________ CYL ________ SMOG ________ ODOMETER ________

FIRST TEST ☐

RETEST NO. __ ☐

TEST RESULTS:

THIS VEHICLE HAS BEEN REJECTED WITHOUT TEST BECAUSE:

☐ REQUIRED EMISSION CONTROL DEVICES WERE FOUND TO BE DISCONNECTED OR MISSING. REPAIR OR INSTALLATION OF PROPER DEVICES IS REQUIRED IMMEDIATELY

☐ EXCESSIVE LEAKS IN EXHAUST SYSTEM

☐ EVAPORATIVE EMISSION LOSS COLLECTION SYSTEM

REMARKS ____________________

INSP. NO. ________ INSP. SIGN. ____________________

Figure 4-8. EXAMPLE OF REJECTION SLIP FOR VISUAL INSPECTION

Failed Vehicles - Should the vehicle fail one or more emission inspection modes, these failures would be denoted by the letter F (for failed) printed after the numeric value, the diagnostic information to be provided would be entered in the Diagnostic Information area. This would be an exception report listing the most probable cause(s) for failure and the measured values for engine parameters used to determine the cause.

The report format would provide a space for remarks to cover unusual problems not covered elsewhere.

Diagnostic Chart - Diagnostic recommendations, selected from the diagnostic chart, and values of key engine parameters would be recorded on the inspection report form. Within the diagnostic chart various parametric criteria would be used to identify the probable cause for high emissions. An abbreviated example of a diagnostic chart is shown in Table 4-26. These charts would be developed by the MVECO and distributed to each test facility upon certification.

Table 4-26. MALFUNCTION TRUTH TABLE

	HC		CO		
Malfunction	High	Very High	High	Very High	Rough Idle
PCV Valve Dirty/Restricted			X		X
Air Cleaner Dirty/Restricted			X	X	
Choke Stuck Partially Closed				X	
Carburetor Idle Circuit Malfunction	X		X		X
Intake Manifold Leak	X	X			X
Ignition Timing Advanced	X				
Leaky Exhaust Valves	X	X			X
Ignition System Misfire	X	X			X

Source: Northrop Study (Ref. 3)

Reports Distribution and Filing - Prior to distributing the inspection reports, the certifying inspector would enter his identification number in the appropriate space and sign the report. He would also stamp the VID card with the facility number and date and return this and the automobile registration card to the owner. After each vehicle's paperwork is completed, Copy 2 would be placed in a basket marked passed or Copy 1 in a basket marked failed. At the end of each day the reports of failed vehicles would be placed in a Retest File in license plate number order. If other failed reports for a given vehicle are already in the file then the motorist should have returned the previous test report and repair summary (Copy 2). Copy 1 of this previous test should be matched to ensure that it is identical to the returned copy, after which Copy 1 can be discarded.

Ultimately there may be one or more failed test reports and repair summaries (Copy 2) and one passed test report (Copy 2) for each vehicle. Periodically, the Retest File would be checked to ensure that failed vehicles have returned for their retest. A query to DMV periodically (perhaps quarterly) by license number, should determine if the vehicle has been subsequently registered, sold, dismantled, abandoned, etc. This action is necessary to purge the files.

For the system to be effective, the failed vehicles must return to the same inspection facility after repair. The method of imprinting facility number and date on the VID card described would provide the necessary control.

Maintenance and Repair Forms - The reverse side of each Vehicle Inspection Report (Copy 2) would be printed with the repair summary form shown in Figure 4-9, and would provide for parts and labor cost information for emission-related repairs. The description of these items would be pre-printed and used as needed. Blank spaces are provided for additional materials or labor actions. Recommended items, as specified by the inspection facility and previously established by the MVD via the diagnostic chart, that were completed by the garage would be so noted. Should additional space be needed, continuation sheets would be used as shown in Figure 4-10. These sheets would be available from the MVD in the form of pads. A fee should be charged for these pads to ensure judicious use.

To ensure that data are not lost, it would be necessary to know when a continuation sheet has been used. Instructions for use would direct the repairing facility to show the total costs only on the continuation sheet (if one is used) and to staple the continuation sheet to the inspection report.

MATERIALS USED

REQ	VOL	QUAN	PART NO.	DESCRIPTION	PRICE
				PCV Valve	.
				Air Filter	.
				Spark Plugs	.
				Points	.
				Condenser	.
				Rotor	.
				Wires	.
				Carburetor Overhaul Kit	.
				Replacement Carburetor	.
					.
					.
					.

LABOR ACTIONS

REQ	VOL	DESCRIPTION	LABOR
		Set Dwell	.
		Set Timing	.
		Adjust Idle Mixture/Speed	.
		Set Idle Speed Only	.
		Repair Choke	.
		Repair Heat Riser/Heated Air Inlet	.
		Repair A.I.R. System/Components	.
		Test Compression ( )( )( )( )( )( )( )( )	.
		Overhaul Carburetor	.
		Replace Carburetor ☐ New ☐ Rebuilt	.
		Perform Low Emission Tune-Up	.
			.
			.

Use Continuation Sheet if necessary. Show totals on continuation sheet.

TOTAL VOL LABOR	.
TOTAL VOL PARTS	.
TOTAL REQ LABOR	.
TOTAL REQ PARTS	.
TAX	.
TOTAL	.

DESCRIPTION OF ADDITIONAL RECOMMENDED REPAIRS	ESTIM.
	.
	.
	.
	.
	.

DATE____________________ ODOMETER____________________

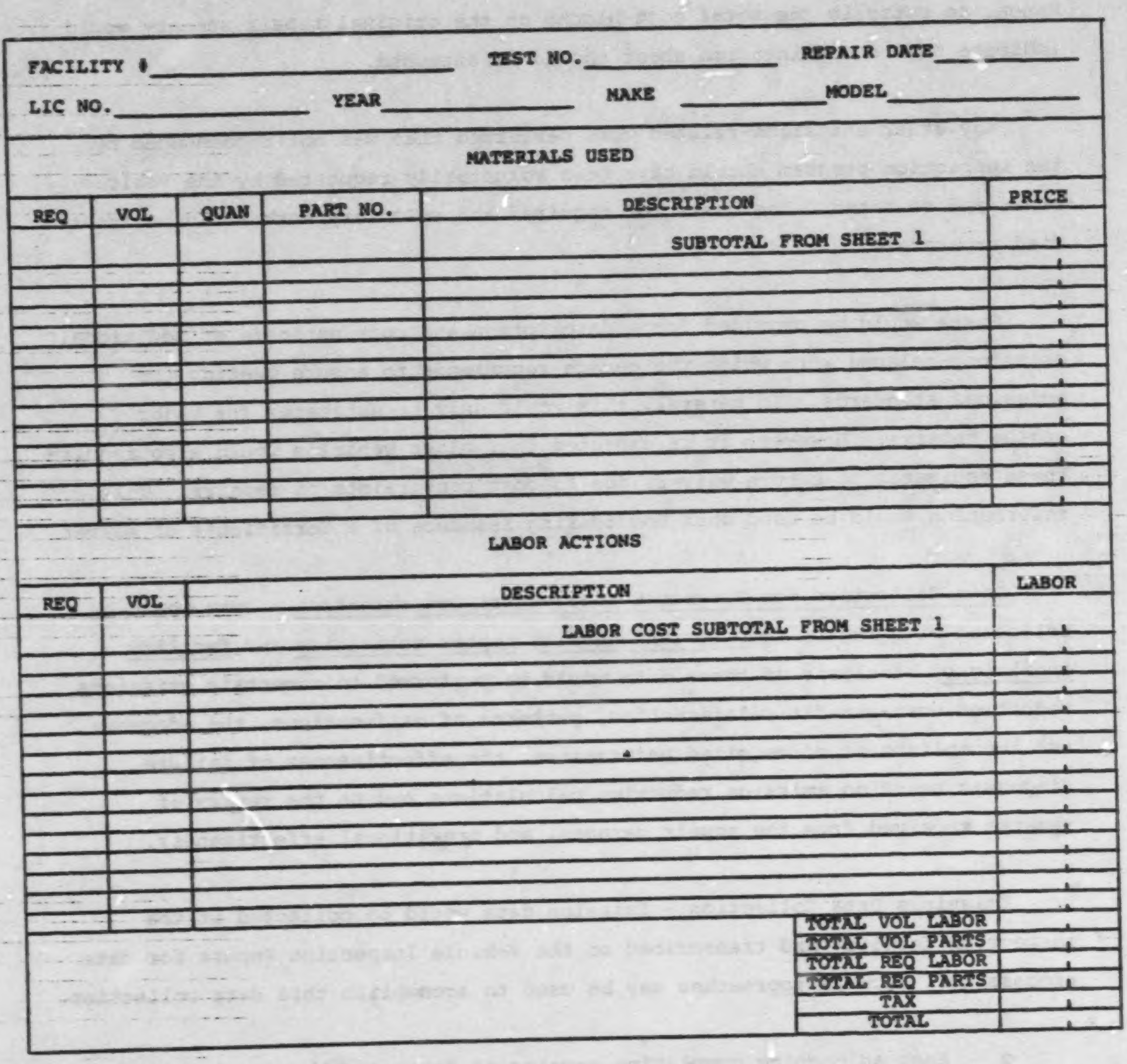
☐ I certify that the recommended maintenance indicated on the reverse side was performed by me or at my request by a mechanic.

Owner Sign.____________________________

☐ I certify that the recommended maintenance indicated on the reverse side have been performed.

Inst. Sign.____________________________

Figure 4-9. EMISSIONS CONTROL SYSTEMS REPAIR SUMMARY



FACILITY # ____________ TEST NO. ____________ REPAIR DATE ____________

LIC NO. ____________ YEAR ____________ MAKE ____________ MODEL ____________

MATERIALS USED

REQ	VOL	QUAN	PART NO.	DESCRIPTION	PRICE
				SUBTOTAL FROM SHEET 1	.
					.
					.
					.
					.
					.
					.
					.
					.
					.
					.
					.
					.
					.

LABOR ACTIONS

REQ	VOL	DESCRIPTION	LABOR
		LABOR COST SUBTOTAL FROM SHEET 1	.
			.
			.
			.
			.
			.
			.
			.
			.
			.
			.
			.
			.
			.
			.

TOTAL VOL LABOR	.
TOTAL VOL PARTS	.
TOTAL REQ LABOR	.
TOTAL REQ PARTS	.
TAX	.
TOTAL	.

Figure 4-10. CONTINUATION SHEET FOR ADDITIONAL REPAIR INFORMATION

Hence, no entry in the total cost blocks on the original repair summary would indicate that a continuation sheet should be attached.

Any other emissions-related work performed that was not recommended by the inspection program should have been voluntarily requested by the vehicle owner and so noted. The costs for required and voluntary work would be identified separately.

Space would be provided for a description and cost estimate of additional emissions-related work which the garage recommends to ensure meeting the emissions standards. In general, this would only be estimates for major engine repairs. However, it is expected that older vehicles would also require these estimates to secure waivers due to cost constraints on repairs. This information would be used when considering issuance of a Certificate of Waiver.

Data Collection for Program Effectiveness Determination - Data would be collected with regard to emissions levels, repair activities and facility operations. Analysis of these data would be performed to ascertain emissions reduction cost-benefit relationships, patterns of malfunctions, the adequacy and accomplishment of required maintenance, the effectiveness of failure diagnosis based on emission reduction calculations and on the review of remarks received from the repair garages, and operational effectiveness.

Emissions Data Collection - Emission data would be collected at the inspection facility and transcribed on the Vehicle Inspection Report for data processing. Several approaches may be used to accomplish this data collection.

- Keep an ongoing cumulative summary of data at each site instead of data on each individual vehicle.
- Collect all data on all vehicles individually.
- Collect all data on all vehicles at a specific site for a specific period (day or week) with the site changed periodically.

All data could be processed at the end of each working day by inspection facility personnel and the summary forwarded to the MVD for inclusion with summaries from each facility. The summary report format can be arranged such that conversion to machine readable form will be expedited.

It is possible to collect all emission data on all vehicles. The purpose would be to gather maximum information to verify emission standards, repair effectiveness and operational effectiveness. These data would be encoded for keypunching each day by inspection facility personnel and forwarded to the MVD for keypunching and inclusion with data from each facility.

To reduce data handling to a minimum it would be desirable to collect all data for a given period, day or week, from a specified facility. A total sample size of 2,000 vehicles out of 0.54 million should be adequate for the first year (1982) of the program. However, the actual sample size required to ensure statistical significance should be determined by observing the mean and standard deviation of these actual data collected during the first year of the program. To ensure randomness of data collection, an assignment algorithm would be used to indicate where and when the data collection would take place.

In the case of a privately-operated facility operating at its projected capacity of less than 5 vehicles per day, a statistical design will need to be developed that will allow sufficient data to be collected over a reasonable length of time from an adequate number of stations. Only then can statistically significant statements be made about that particular facility's measure of effectiveness. For the total program, data from all of the sites sampled will be combined for an overall effectiveness measure.

Data Encoding to Machine Readable Form - Data may be transcribed from the printed Vehicle Inspection Report (VIR) onto an 80-column coding sheet which could then be keypunched at the State Data Processing Center for input to a computerized data analysis program. The punched card format shown in Figure 4-11 includes the data for each test on each vehicle. The order of data entry follows the order of listing on the VIR. The data would be encoded as a series of cards after a Certificate of Compliance or Waiver had been issued--

the day of first test for passed vehicles or several days (or weeks) later for failed vehicles. Daily operational information would be tallied separately.

Two problems must be considered for this method of data handling-transcription errors and time expended. Transcription errors cannot be totally eliminated but can be reduced by using a coding form that clearly identifies each data field by title, by using heavy separating lines between fields, by blocking out fields that must be blank, by coding in the same order as data are read, and by fixing decimal points wherever possible. An example of this technique was shown in Figure 4-11.

Time required to fill in these forms and to keypunch the data must be considered. Using a conservative estimate of 50 seconds for manually recording the first test (the only test in the case of passed vehicles), and 40 seconds for each additional test (since descriptive data need only be recorded once), a 35 percent inspection failure rate, a 10 percent reinspection failure rate and 5 tests or retests per facility per day, it would require less than 5 minutes per facility per day for recording all data manually.

The manual method of data recording applies equally well to the collection of data at a specific site for a specific period.

Repair Cost Data Collection - Cost data on repaired vehicles would be derived from the repair summaries filled out by the repairing facility and returned by the vehicle owner at the time of retest. These data must be transcribed manually to a machine readable form. Assuming 5 tests per facility per day, an average of 3 minutes per repair summary will be required for interpretation and coding or about 6 minutes per day per facility.

To provide meaningful cost breakdowns for subsequent data analysis, it will be necessary to identify parts and labor for recommended maintenance separate from voluntary maintenance. This would allow determination of an average cost figure for each of the required maintenance items which can be used in identifying excessive charges. Distinguishing recommended from voluntary maintenance would also aid the consumer by imposing a limitation on the

Card Cols	Item	Example	Remarks
1-4	Facility number	x111	Constant for each facility
5	Lane number	4	Each test
6	Space		Constant
7-12	License number	123ABC	Each test-for traceability
13-14	Model year	70	Once in a series
15-16	Weight class	x1	
17-18	Number of cylinders	x8	
19-20	Emission control code	x3	
21-23	Odometer (in 1000s)	x42	
24	Space		Constant
25	Test number	1	
26	Test Decision- Failed = 1	blank	
27-30	Idle HC	x150	For each test
31-35	Idle CO- Fixed Decimal in Col 33	x0.49	
36-39	Lo Cruise HC	x121	
40-44	Lo Cruise CO- Fixed Decimal in Col 42	x0.38	
45-48	[illegible]		
49-52	Hi Cruise HC	x123	
53-57	Hi Cruise CO Fixed Decimal in Col 55	x1.01	
58	Space		Constant
59	Required maintenance- Not completed = 1	blank	
60-62	Required Parts Cost - Dollars	xxx	For each retest
63-65	Required Labor Cost - Dollars	xxx	
66-68	Voluntary Parts Cost - Dollars	xxx	
69-71	Voluntary Labor Cost - Dollars	xxx	
72	Space		Constant
73-75	Parts Estimate-Dollars	xxx	For waiver consideration
76-78	Labor Estimate-Dollars	xxx	
79	Space		Constant
80	Waiver-Granted = 1	blank	

NOTE: x is used to show number of available field positions

Figure 4-11. MANUAL DATA ENCODING FORMAT

repair garage, and would aid the MVD in identifying repair garages that fraudulently indicate that some voluntary items are required.

An analysis of the repair summary would be made by comparison with a matrix of failure diagnosis versus recommended actions to determine whether:

a. Fewer than the recommended actions were performed.
b. Only the recommended actions were performed.
c. Only recommended and voluntary actions were performed.
d. Excessive actions were performed and indicated as being required.

The result would be encoded along with the given cost data. The Vehicle Repair Summary (Figure 4-9) can be encoded for direct keypunch operation. To facilitate data encoding, the following definitions of correct, excessive, insufficient and incorrect repairs are proposed.

Correct Repairs - A correct repair may be implied if the vehicle passes the retest and the recommended repairs were performed. Additional and voluntary repairs may also be allowed.

Excessive Repairs - The vehicle may pass the retest, but more may have been repaired than was required. It would require considerable test and maintenance data to assure the MVD that only those repairs identified as recommended are sufficient to ensure passing a retest.

Insufficient Repairs - Insufficient repairs would be implied if the vehicle fails the retest. Less than the recommended repairs may have been performed and this can be determined from the repair summary. The recommended repairs may have been completed but the list of repairs or the procedure for a given failure diagnosed may be lacking completeness. It is also possible that more than the recommended repairs were performed and it could still be insufficient since the "correct" diagnosis was not performed.

Incorrect Repairs - If the vehicle fails the retest and fewer than (or none of) the recommended repairs were performed but other repairs were performed, the repair can be considered incorrect. It might also be possible that incorrect repairs were performed due to faulty garage equipment. To identify this possibility, measured engine parameter data should be collected in the early stages of implementation and whenever a vehicle returns to the repair facility after failing a retest. It is possible to have both excessive and incorrect repairs.

Operations Data Collection - There are numerous items of data that would be collected to determine the effectiveness and efficiency of the inspection facilities. These data would include daily tallies of:

- Inspections completed - Pass, Fail, and Fail Retest from VIR copies. Additional breakdowns would be accomplished as part of emissions data analysis.
- Vehicles rejected - Cause, as determined from copies of reject reports.
- Complaints processed - Complaints received, resolved and forms forwarded for investigation.
- System Performance (as determined from system log) - Number of hours in operation, scheduled maintenance - by equipment, unscheduled maintenance - by equipment.

These tallies would be performed during the day following the day of operation being reported on. A sample of an operations worksheet is shown in Figure 4-12. Completion of this log would require less than 3 minutes per day per facility. An additional 2 minutes would be required to collect and organize the data and check it for completeness.

Data Conversion - All cost and operations data would require keypunching from coding sheets. Assuming a total of 1,480 tests per day, keypunching of manually collected emissions data would require less than 5 hours per day (at 160 to 200 cards per hour). This punching would be done at the State Data Processing Center or by a service bureau.

	Date		Date		Date		Date		Date		Date		Week Total	
Inspections Completed														
Pass														
C of Cs Issued														
Initial Failure														
Failed Retest 1														
Failed Retest 2														
Waivers Issued														
Vehicles Rejected														
Retrofit Lacking														
Control System Inoperative														
Brakes														
Exhaust Leaks														
Fluid Leaks														
Complaints Processed														
Received														
Resolved														
Forwarded														
Hours of Operation														
Lane 1														
Lane 2														
Lane 3														
Lane 4														
Maintenance Hours	**Sched**	**Unsched**	**Sched**	**Unsched**	**Sched**	**Unsched**	**Sched**	**Unsched**	**Sched**	**Unsched**	**Sched**	**Unsched**	**Sched**	**Unsched**
Lane 1														
Equipment A														
Equipment Z														
Lane 4														
Equipment A														
Equipment Z														

Figure 4-12. EXAMPLE OF DAILY OPERATIONS SUMMARY WORKSHEET

5. Legislative Considerations

In designing an I/M program, there must be careful consideration of potential problem areas that could hinder acceptance by the State Legislature. These potential problem areas are the result of secondary impacts that may be unforeseen by program designers. These secondary impacts include political constraints, socioeconomic considerations, and institutional effects. These impacts are wide in scope, illustrating the pervasive effects of I/M on the population. Among the more important secondary impacts, the following require early legislative consideration:

- Impact on those groups that must subsist on low or fixed yearly income (e.g.; the poor, the disabled, and the elderly).
- Impact on the repair industry.
- Consumer protection.

a. Impact on Low-Income Groups

A major concern posed by consumer protection groups, legal aid societies, etc., involves the effect of I/M on low-income groups. It is felt that since older vehicles as a group are more likely to be seriously out of compliance with emission standards, the maintenance cost would be prohibitive and, in effect, deny low-income citizens the right to operate older vehicles.

This problem can be remedied by establishing exemption criteria for certain vehicles requiring costly emission-related work to be performed. One criterion involves a repair cost ceiling based on an absolute dollar figure, or the percentage of vehicle value--whichever is lowest. The second criterion would exempt vehicles of a certain age (e.g.; pre-1952, antique vehicles). Both criteria would substantially reduce the cost burden on low-income groups.

These exemptions would not have a significant effect on the I/M program effectiveness on reducing emissions from the in-use vehicle population. The majority of vehicles that are seriously out of compliance with established emission standards tend to be older (5 years), and probably would not remain in the vehicle population much longer. Resale vehicles that filter down over time to replace the gross emitters would have been maintained as a result of I/M and should not be as costly to keep in compliance.

A potential problem area requiring legislative resolution involves the question of warranty protection. Presently, emission devices are subject to a 50,000 mile/5-year manufacturer's warranty. In most cases, the warranties on older vehicles owned by low-income groups have expired. This places a burden on low-income groups that are required to replace costly emission control devices. It should be mentioned that it is unknown how long these durable devices will last and may conceivably remain operative until the end of the vehicle's useful life.

b. Impact on the Repair Industry

The repair industry has considerable lobbying power that may be exerted on the legislature. Areas of special concern involve questions of how I/M will affect the ability of the repair industry to maintain vehicles; the accuracy of the HC/CO analyzer; the ability to profitably finance program equipment; and, finally, new rules, regulations, and restrictions that may be placed on the repair industry. These questions can certainly be voiced and perhaps resolved through committees and public hearings.

c. Consumer Protection

Legislative provisions must be made to ensure that vehicle owners are protected from abuses that could appear in the maintenance phase of an I/M program (e.g.; overcharging, unnecessary repairs, and warranty protection). Section 4.E.2 provided descriptions of various program issues that should be adequately covered by initial legislation. As program development advances, it is likely that other issues will surface requiring revision or modification of initial legislation.

d. Legislative Implementation

The first stage in the implementation of an I/M program is the development of appropriate enabling legislation. For the drafting of the enabling legislation, a preliminary description of the major program components should be prepared and the organizational option should be decided upon. Program objectives, operating rules, program scope and major agency responsibilities should be specified. Planning and trade-off studies will result in the identification of the technical, social, and economic characteristics of the desired I/M program. This aids in the structuring of the legislation.

Several states have already passed legislation establishing legal requirements for the control of emissions of HC, CO, and NO_x from motor vehicles. In some cases, this has been accomplished by either an act of the State Legislature, or through official action taken by an air pollution control board, commission, or other state agency. Either method is acceptable, depending on the legal requirement of individual states, so long as a firm legal authority is established under which necessary action can be taken.

Generally, most of these laws and regulations include two provisions. The first is a legal requirement that the owner or operator of a motor vehicle should not deliberately remove or inactivate the emission control devices presently required of automobile manufacturers.

The second provision establishes a system of inspection and/or maintenance programs. This provision would address specific issues (i.e.; legal authority, fees, penalties), that should be incorporated into the enabling legislation such as:

- Adequate authority to adopt rules and regulations concerning:
  -requirements for periodic inspection

  -establishment of fees for providing the inspection service

-withholding vehicle registration for those vehicles that do not satisfactorily complete the inspection or that do not comply with an applicable emission variance

-prohibition of tampering

-vehicle exemption.

- Provisions for providing adequate funds for implementing, monitoring, and enforcing the I/M program.

- Adequate authority to obtain pertinent data and information, and require periodic reporting of emission information.

- Authority to develop emission reports and information suitable for public inspections.

- Authority to compel compliance with rules and regulations, supported by civil or criminal penalties.

- Provisions for injunctive relief where deemed necessary.

- Provisions for public hearings.

6. Mechanics Training

A high level of skill and technical competency of automotive mechanics is required to repair, diagnose, and adjust vehicles to emission standard levels. This implies that mechanics must be thoroughly familiar with the underlying principles, theory, and operation of emission control devices. However, this becomes increasingly difficult owing to the great diversity of vehicles, profusion of various makes/models/years, and their associated emission devices. This problem becomes compounded by the fact that emission control technology is becoming increasingly more complex. The end result is an apparent shortage of qualified mechanics capable of correctly diagnosing engine parameters.

In order to ensure that enough qualified mechanics are available to service and repair vehicles according to I/M specifications, present educational programs should be upgraded to meet the current and future needs of the repair industry. This may be accomplished, prior to implementation of I/M, if the state takes an active role in formulating criteria that evaluate, train, and assist currently employed mechanics. These criteria would include:

- Mechanic training curricula which incorporate multimedia aids that review step-by-step emission tune-up techniques.
- Assessment of mechanic qualification requirements, and development of qualification examinations.
- Conducting pilot programs to evaluate the effectiveness of training programs.

Each criterion will be covered in greater detail in the following subsections.

a. Mechanic Curricula

There is a wide variety of mechanic training programs currently available at the various trade, vocational, and technical schools. These programs will differ in content because of the different degree requirements of each school. Unfortunately, many of these programs either ignore or superficially cover the effects of various engine parameters on vehicle emissions. This problem can be remedied if a standardized and comprehensive emission control training program is instituted at selected schools.

As part of this comprehensive training program, an EPA-approved emissions control course would become mandatory. Colorado State University has recently published a "Motor Vehicle Emissions Control Instructional Materials Packet" that has been extensively field tested and widely accepted by many states. This packet is designed to be used by vocational automotive instructors as a complete multimedia approach to emissions control systems. The topics that are covered in-depth include: positive crankcase ventilation, thermostatic air cleaner, air injection reaction, fuel evaporation, exhaust gas recirculation, spark control, and catalytic converters.

Once the fundamentals of emission controls are covered in sufficient detail, supplemental courses (Table 4-27) could be made available to emission inspectors and repair mechanics alike. These courses would add greatly to the mechanics understanding of the needs, concepts, and requirements of an I/M program.

An important by-product of a mechanic training program would be the development of a handbook that describes definite repair sequences for each type of emission failure. Mechanics would be instructed to proceed only so far as the step that corrects the particular malfunction. This would alleviate unnecessary repair work.

b. Mechanic Qualification/Certification

Before state-approval is given to perform emission repair work, a mechanic should be required to demonstrate proficiency by:

- Successfully completing the required number of training courses.
- Correctly diagnosing and repairing control vehicles to meet emission requirements.
- Passing qualification examinations designed to test the mechanic's understanding of the principles and theory underlying emission control devices.
- Demonstrating a working knowledge of Federal and State laws and regulations governing emission control.

Upon the successful completion of the above requirements, the mechanic would be certified.

Table 4-27.
CONTENT OF TRAINING COURSES

COURSE TITLE	COURSE HOURS	SUBJECTS	EQUIPMENT AND DOCUMENTS
Program Orientation	1-2	Objectives of and general procedures used in periodic inspection and maintenance. Program structure including organization charts, and relationships to other State and local agencies. Relationship of PVI to other air pollution control strategies. Data flow within agency and between related agencies. Enforcement procedures for vehicle owners and repair facilities. Consumer information and protection measures.	Slide/tape or sound movie presentation including pictorial and diagramatic visual aids. Question and answer period follows. Distribute Consumer's Handbook.
Vehicle Emissions and Standards	7-8	General discussion of mechanisms producing hydrocarbon, carbon monoxide, nitric oxide and smoke (particulates) emissions. Concepts of normal emission levels and excess emission levels. Effect of factors such as misfire, air/fuel rations, and combustion temperature on emission levels. Emission standards and regulations mandating particular OEM or retrofit equipment. General types of emission control systems, including general configuration, theory of operation and typical effect on emission levels at different engine operating conditions. Identify differences in standards set for emission inspection and original manufacturer certification. Identify distinction between Federal and Georgia standards and equipment configurations by model year.	Film or videotape presentation including pictorial and diagramatic visual aids. Distribute training manual on emission controls and standards.
Inspection Procedures	21-24 (1st day)	Facility layout. Description, purpose and use of principal equipment. Facility personnel organization, shifts, duties, and authority of each inspector. Vehicle traffic flow through facility. Public relations and manner of dealing with the motorist.	Film or videotape presentation showing actual facility and equipment configuration. Provide training manual to trainees.

Table 4-27.

CONTENT OF TRAINING COURSES (Continued)

COURSE TITLE	COURSE HOURS	SUBJECTS	EQUIPMENT AND DOCUMENTS
	(2nd day)	Specific inspection procedures for each work station. Procedures for visual inspection. Specific vehicle emission control equipment configurations by model year. Exemptions. Retrofit requirements. Examples of equipment violations. Procedures for connecting ignition analyzer and exhaust probe. Emission inspection driving pattern. Interpretation of test results. Consulting with driver on vehicle results. Grounds for waiver.	
	(3rd day)	Laboratory practice in facility or lane mock-up. Each inspector performs at each work station for 1 hour performing inspections on sample vehicles. Emphasize order of tasks, completeness of visual inspection, accuracy of driving inspection test, interpretation of results, dealing with the public. Set-up and calibration of equipment. Start-up and shutdown of facility. Certification of inspection personnel and assignment to facility.	Inspection lane, either in facility or mock-up at training center. Duplication of equipment used in actual facility.
Repair Procedures	4	Ignition and carburetor systems. Emission control systems. Diagnosis of engine malfunctions using scope and and infrared analyzers. The service warranty and criteria for satisfactory performance. Completing, signing, and returning repair forms and estimates, information required, and method of entering data.	Film or videotape of vehicles being tested and repaired for typical malfunctions. Issue mechanics a certificate and note attendance. Distribute Repair Procedures Manual.
Fleet-Owner Inspection and Maintenance	7-8	Describe the emission test. Show typical test bay with gas analyzers. Describe data recorded. Explain various emission standards. Calibration and use of gas analyzers. Diagnosis of failures using emission data. Use of ignition scope in diagnosing HC failures. Reporting of information and retention of records. Spot surveillance of vehicles and test facility. Cost savings of inspection for directing vehicle maintenance activity.	Film or videotape of inspection process and emission related repairs. Training manual defining procedures and guidelines.

Table 4-27.

CONTENT OF TRAINING COURSES (Continued)

COURSE TITLE	COURSE HOURS	SUBJECTS	EQUIPMENT AND DOCUMENTS
Administrative Procedures	3-4	Specific procedures for recording, transmitting, and reporting test data and requisitioning supplies and services. Administrative, personnel, budgetary, and public relation policies and procedures. Management procedures.	Training manual and film or videotape presentation

c. Mechanic Training Program Costs

In order to develop costing information for implementing mechanic training programs, it was necessary to assume that state safety inspection stations would provide the minimum number of mechanics necessary to support emission repair activity. Hence, at least 650 mechanics, one from each of the safety inspection stations will participate in the training programs.

The program costs for training 650 mechanics are shown in Table 4-28. These costs were developed by assuming that at least 30 mechanics would enroll in each class taught by vocational instructors at local colleges, trade schools, etc.

The estimated $12 thousand can be defrayed by charging a tuition of $50 per student. This would produce annual revenues of $32,500. This can be allocated to pay instructors fees, capital and operating costs, etc. The remaining funds can be used for an on-going training effort in the form of seminars, workshops, etc. This will upgrade certification requirements and help keep mechanics current with new information.

Table 4-28. ESTIMATED PROGRAM COSTS FOR MECHANIC TRAINING

COST CONSIDERATIONS	COSTS
A. Capital Costs:	
Audio visual materials[a]	$ 1,200
B. Operating Costs:	
1. Personnel planning, curricular development and class scheduling[b]	3,500
2. Personnel 11 instructors[c]	7,480[d]
Total	$12,180

[a] Materials estimated at $200 per course - projection slides, charts, etc. There are 6 courses in training program.

[b] Program coordinator's time at $6.80/hr. Estimate 3 months planning and development.

[c] Assuming 1 instructor can teach 2 classes per day at 3 hours per class meet ing, then the number of instructors required is calculated.

$$(22 \text{ classes}) \ \frac{1 \text{ instructor}}{2 \text{ classes}} = 11 \text{ instructors}$$

[d] State vocational instuctors receive approximately $13,600/yr or $6.80/hr. Each class will require 50 hours in class instruction or $340/class.

7. Decentralized I/M System Minimum Station Requirements

The I/M option established by the State of South Caroline is the decentralized system (a system of private garages for emissions testing). An I/M option available to the State of South Caroline involves consideration of private-garage emission inspection facilities. This section is an analysis of the minimum number of emission testing stations and their location.

In estimating the minimum number of private garages involved in emission inspection and the service coverage for each garage, the following assumptions were used:

- Projection vehicle registration data for 1977 (base year), 1982, and 1987.
- Thirty percent (i.e., stringency factor) more inspections than actual registrations.
- Capital Investment Per Station
  -$3,000 - Cost of emission testing and auxilary equipment
- Operations Throughput Time
  -3.75 minutues
- Mechanics Costs (including overhead)
  -$18 per hour
- Station inspection work load factor capability for private garage - 10 percent of work load assigned to emission inspection. In the four county area with safety inspection stations the work load factor for emissions testing is about 3 percent.
- Emissions for statewide option were developed by extrapolating the four county data.
- Cost of capital is 6 percent for the state.

- The state personnel benefits including sick leave, vacation, retirement, insurance, holidays, etc., is 25 percent of base rate.

- Fuel cost is \$.70 per gallon.

- Inflation rate is 7 percent. To convert from 1978 to 1982, a compound factor of 1.31 must be used.

- Indirect costs reflecting the cost to consumers for waiting time at inspection lanes and cost of transportation to and from the inspection and repair facilities were ignored.

- Average miles traveled per year for LDVs is 11,500 miles per year.

- Failed vehicles consumed an average of 3.8 percent more fuel than the certified vehicle.

- Fleet fuel economy for LDVs is 15 miles per gallon (1982), 24 miles per gallon for 1987 LDVs.

- Emission testing, without supplemental diagnostic testing, requires at least 3.75 minutes per test.

- Ten percent of station business is emission-inspection related.

a. Minimum Number of Private Garages

The minimum number of private garages directly involved in emission testing is calculated using the following formula:

$$G = \frac{(V_r + V_r S_f)}{I}$$

where:

G = the minimum number of private garages

V_r = vehicle registration data

S_f = stringency factor = .30

I = number of vehicles inspected by each garage per year (2,200 inspection/year)*

Using the methodology outlined above, the minimum number of private garage emission inspection stations for each county are presented in Table 4-29. It is expected that the total vehicle population will increase over time. Hence, the number of garages involved in inspection will change accordingly. For instance, the number of additional stations at 5-year intervals, for each county are as follows: Lexington and Charleston Counties 15 to 17 additional stations; Richland 19 to 20 stations; and Berkeley, 9 stations.

Table 4-29. PROJECTED PRIVATE GARAGE EMISSION TEST STATIONS REQUIRED FOR EACH COUNTY

COUNTY	1977 (Base Year) NO. OF GARAGES	1982 NO. OF GARAGES	1987 NO. OF GARAGES
Lexington	52	64	82
Richland	92	111	131
Berkeley	25	34	42
Charleston	90	106	123
	259	318	378

b. Service Area Radius

In order to calculate the service area coverage for each garage, it is necessary to make certain fundamental assumptions. First, no motorist need drive more than a certain distance, R, to an inspection station. Second, assuming cars and service garages are spread evenly across the landscape, this distance is the radius of the service area of each station, and R^2 is its service area or coverage. Given a number of service garages within a given area, R can be calculated using the following formula:

$$R = \left[\frac{A}{\pi G}\right]^{1/2}$$

---

*Work burden devoted to emission inspection was assumed to be 10 percent.

where:

R = service area radius

A = county area

π = 3.14159

G = number of private garages in each county

The service area radius for all garages within each nonattainment county is shown in Table 4-30. The calculated service area radius are comparable for all counties ranging from 26 to 32 miles. The service area radius decreases as the number of private garages increases over time.

Table 4-30. SERVICE AREA RADIUS FOR PRIVATE GARAGE TEST STATIONS IN EACH COUNTY SERVICE AREA RADIUS (Miles)

COUNTY	1977	1982	1987
Lexington	23	21	19
Richland	29	26	24
Berkeley	27	23	21
Charleston	30	27	25

Section 5

STATEWIDE I/M PROGRAM ANALYSIS

This section presents the statewide I/M program option. The scenario for this option is as follows:

- Area - statewide I/M program
- Test mode - idle
- Vehicle category - LDV, LDT_1, and LDT_2
- Administration - private garage
- Enforcement - vehicle registration
- Emission check - HC and CO

A. FACILITIES REQUIREMENTS

For the statewide option there are 3,135 private garages that would participate.

B. PERSONNEL REQUIREMENTS

Table 5-1 lists the State personnel requirements for the four-county area and the statewide program options. The State personnel requirements do not have a one-to-one correspondence to the number of vehicles because the minimum effort of program administration is independent of the number of vehicles. For example, the number of inspection agents is based upon a calibration check at each station every two weeks.

Table 5-1. I/M STATEWIDE MANPOWER REQUIRMENTS[a]

JOB CATEGORY	STATEWIDE
Program Administrator	1
Assistant Program Administrator (Quality Control)	1
Assistant Program Administrator (Testing)	1
Environmental Engineer	2
Statistician	2
Clerical	8
Secretaries	2
Inspection Agents[b]	43
TOTAL	60

[a] Salaries are presented in Table 4-10.

[b] Including 8 quality control field personnel.

Program management responsibilities for either option will include: 1) vehicle testing scheduling, 2) record maintenance, 3) establishment and review of emission test limits, 4) data analyses to determine inspection program effectiveness, 5) evaluation of current and future equipment needs, and 6) provision for future analyses and development. These program responsibilities will be coordinated by three key state personnel positions: 1) Quality Control Assistant Program Administrator, 2) Testing Assistant Program Administrator, and 3) Environmental Engineer. The specific responsibilities for each management position is outlined as follows:

1. Assistant Program Administrator (Quality Control) - Will manage the twice-monthly equipment calibration checks for all private-garage inspection centers; the statistical analysis of emission test data.

2. Assistant Program Administrator (Test) - Will be responsible for the efficient day-to-day operation of referee test stations.

3. Environmental Engineer - Is responsible for monitoring program effectiveness and evaluation of vehicle emission reduction.

C. EMISSIONS REDUCTION

The HC/CO emissions for statewide I/M program are as follows: the reductions for HC in the year 1982 is 6 percent and in the year 1987 it is 23 percent. The CO reductions in the year 1982 is 16 percent; in the year 1987 it is 34 percent.

D. COSTS OF A STATEWIDE PROGRAM

The costs of a statewide program are presented in Table 5-2. In contrast to the four-county option, the total capital costs for 3,135 private garages at $6,000 per garage is $18.8 million. This will require an annualized cost for capital equipment $700 per year per private garage. The private garage operation costs over the 10-year period is $28.5 million or $9,000 per private garage. This amounts to $900 per private garage per year and a total cost per year for capital and operation costs of $1,600.

The statewide operation costs of each private garage is less than that of the four-county option because they will not inspect as many vehicles per garage. The operating costs per vehicle is equal for each option.

The State cost of $22.2 million or an average of $2.22 million per year over the 10-year program is to cover 1) 15.1 million for operating administrative costs to support analyses of data, prepare reports, administer the program, investigate complaints and consumer protection, $5.7 million for increased quality control of the 3,135 private garages, 2) initial implementation costs of $202,000 and $200,000 for public information, and 3) other capital costs of approximately 1 million consisting of $41,000 for administrative equipment, $575,000 for quality control equipment and $377,000 for consumer protection capital cost.

The State costs increase was considered to be proportional to the large increase of participating private garages which was a 4.7 fold increase over the four-county options.

Table 5-2.

COSTS OF SOUTH CAROLINA I/M PROGRAM - STATEWIDE OPTION[a]
($1,000 1978 Dollars)

CATEGORY	1982-1986 State	1982-1986 Private Garage	1987-1991 State	1987-1991 Private Garage	TOTAL State	TOTAL Private Garage
I Test Equipment Costs[b]	0	9,405.0	0	9,405.0	0	18,810.0
II Operating Costs						
Facility Operation[c]	0	13,053.6	0	15,508.5	0	28,562.1
Administrative Support[c]	7,552.5	0	7,552.5	0	15,105.0	0
Quality Control[c]	2,859.3	0	2,859.3	0	5,718.6	0
III Initial Implementation Costs[c]	202.0	0	0	0	202.0	0
Public Information	200.0	0	0	0	200.0	0
IV Other Capital Costs						
Administrative Office Equipment[c]	41.1	0	0	0	41.1	0
Quality Control Equipment[c]	575.7	0	0	0	575.7	0
Consumer Protection[c]	377.4	0	0	0	377.4	0
TOTAL	11,808.0	22,458.6	10,411.8	24,913.5	22,219.8	47,372.1
TOTAL STATE & PRIVATE GARAGE	34,266.6		35,325.3		69,591.9	

[a] Costs are to the closest $100.

[b] 3,135 private garages would be participating in the program.

[c] Costs for statewide option are considered directly proportional to the number of stations participating in the program.

The total operating and capital cost for the statewide option program is approximately $69.5 million. The gross estimate under this option was to provide general comparative data only.

E. CONSUMER FEE

In order to compute consumer fee, the program costs for the statewide option in Table 5-2 were converted into annualized costs. This was done by amortizing capital-related (categories I, IV, and V) over 10 years of program operation. Results are presented in Table 5-3. Cost of capital was assumed to be 6 percent.

The average consumer fee to defray the statewide option I/M program cost was estimated to be $3.48 (see Table 5-3). The State's share is $1.06, while the private garage's share is $2.42. The average vehicle population for the statewide option was 2,103,000 vehicles. The increased cost for the statewide option is because the costs of equipment and operations requirements of 3,135 participating private garages. The participating garages for the statewide program would be testing fewer vehicles then the participating stations in the four-county option.

It should be noted that the fee covers only the State's direct cost on the I/M program and certain indirect costs, such as utilities/supplies, office rental, etc. It is difficult to include all governmental indirect costs in this study without a detailed knowledge of the state's general accounting procedure.

Table 5-3. ANNUALIZED COSTS OF I/M PROGRAM[a,b] - STATEWIDE
(1978 DOLLARS)

CATEGORY	TOTAL AMORTIZED COST[c]	AVERAGE ANNUALIZED COST ($/YR)
I. Test Equipment Cost		
private garage	$9,405,000 x 0.2374 x 5^d + $9,405,000 x 0.2374 x 5^d = $22,327,500	$22,327,500/10 = $2,232,700
II. Operating Costs		
private garage	$28,562,100 facility operating	$28,562,100/10 = $2,856,200
state		(15,105,000 + 4,718/500)/10 = $2,082,400
III. Initial Implementation Costs - state	$202,000 x 0.1359 x 10 = $274,500	$274,500/10 = $27,500
IV. Other Capital Costs		
state	(41,100 + 575,700 + 377,400) x 0.1359 x 10 = $1,351,100	$1,351,100/10 = $135,100
Total - State		$5,088,900
Private Garage		$2,245,000
State and Private Garage		$7,333,900

[a] All costs are rounded off to hundred dollars.

[b] Basic capital and operating cost data is taken from Table 6.

[c] Amortization factor (F) is determined by the formula.

$F = i(1 + i)^n/1 + i)^n -1$ where i is the cost of capital (= 6%) and n is the number of years.
For equipment amortization of 5 years, F = 0.2374
For capital amortization of 10 years, F = 0.1359

[d] Equipment life is considered 5 years, therefore, it is required to replace equipment after 5 years.

NOTE: Fee Calculations

$$\text{private garage share} = \frac{\$5,088,900}{2,103,000 \text{ vehicles}} = \$2.42$$

$$\text{state share} = \frac{\$2,245,000}{2,103,000 \text{ vehicles}} = \$1.06$$

TOTAL FEE $3.48

Section 6

SPECIAL TOPICS

A. REFEREE STATIONS

Customer complaints will arise regarding the reliability of emission test results, especially in cases where a vehicle fails an emission test after the recommended repairs have been performed. In order to resolve complaints of this nature a referee station can be used. The use of a referee station will also provide an additional check on emission test facility instrumentation, engine diagnosis, and mechanic capability.

The configuration of a referee station is presented in Figures 6-1 and 6-2. The costs of a referee station is presented in Table 6-1. For the following capabilities:

- FTP testing capability
- Loaded mode and diagnostic testing (minimum system)

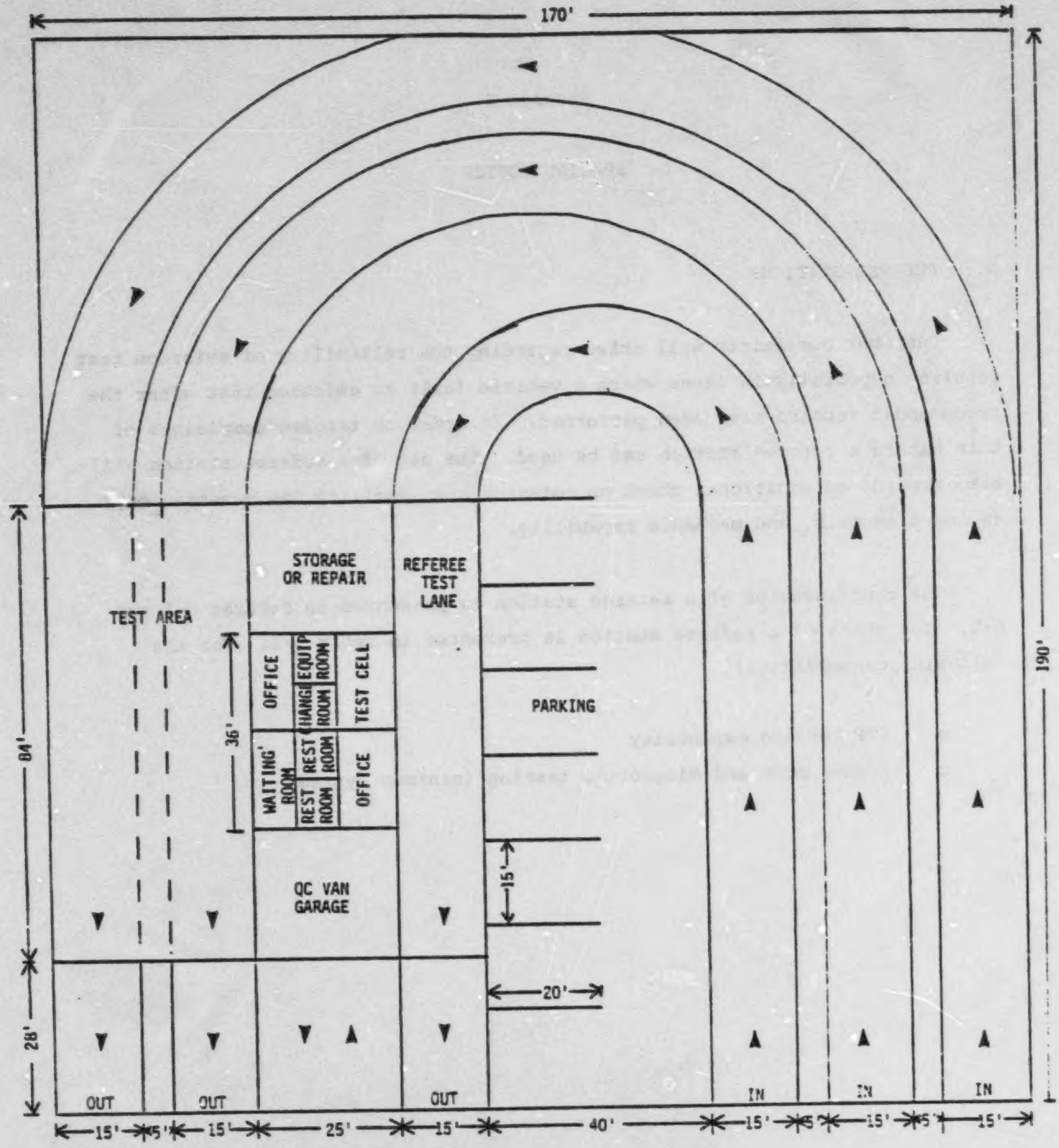

170'
190'
84'
28'
36'
15'
20'
TEST AREA
STORAGE OR REPAIR
REFEREE TEST LANE
OFFICE
EQUIP ROOM
CHANGE ROOM
TEST CELL
WAITING ROOM
REST ROOM
REST ROOM
OFFICE
QC VAN GARAGE
PARKING
OUT
OUT
OUT
IN
IN
IN
15'
5'
15'
25'
15'
40'
15'
5'
15'
5'
15'

Figure 6-1.
THREE-LANE/REFEREE FACILITY

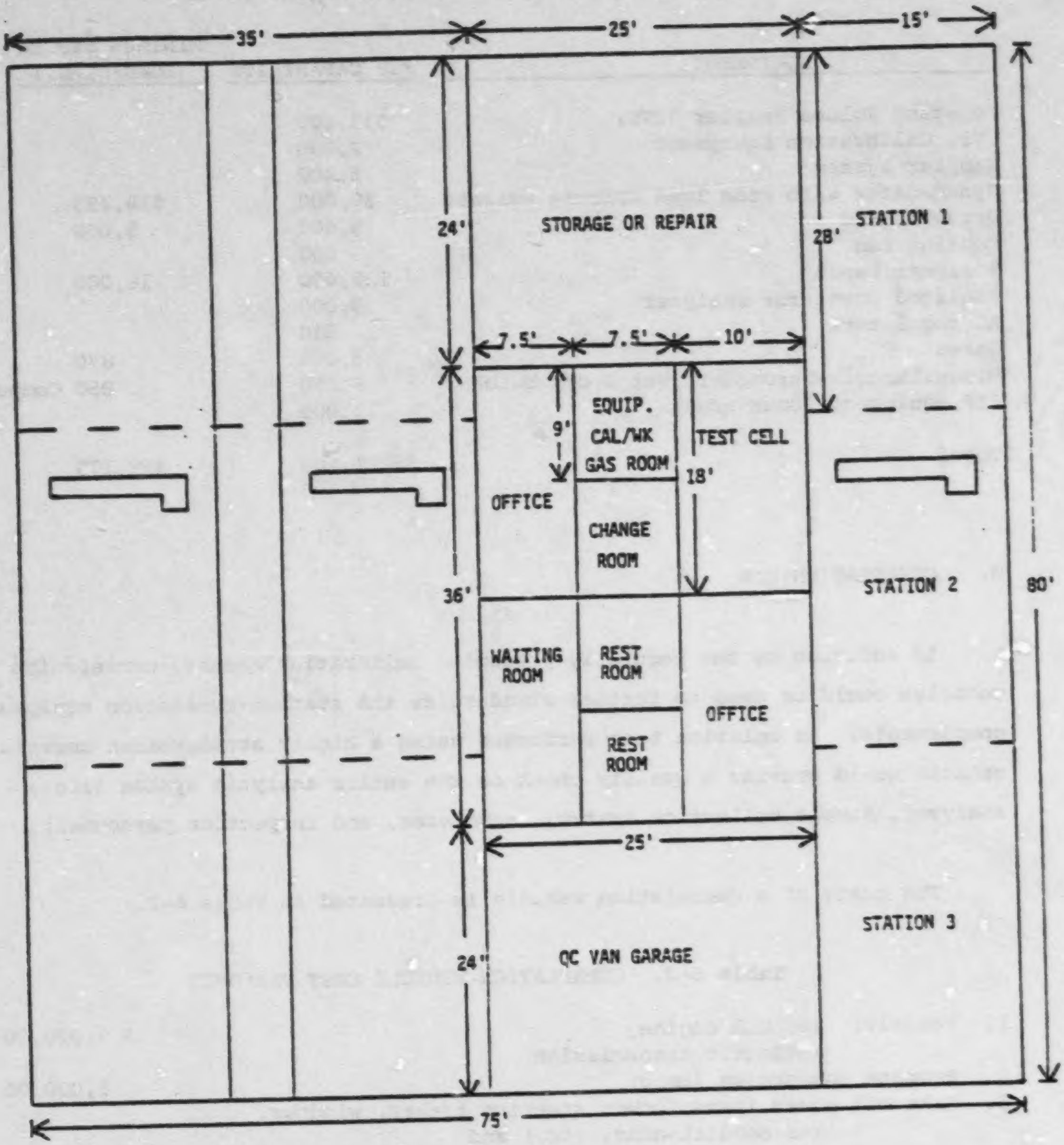

35'
25'
15'
24'
STORAGE OR REPAIR
28'
STATION 1
7.5'
7.5'
10'
9'
EQUIP.
CAL/WK
GAS ROOM
TEST CELL
18'
OFFICE
CHANGE
ROOM
36'
STATION 2
80'
WAITING
ROOM
REST
ROOM
OFFICE
REST
ROOM
25'
STATION 3
24"
QC VAN GARAGE
75'

Figure 6-2.
INNER OFFICE AND TEST AREA
THREE-LANE/REFEREE FACILITY

Table 6-1. REFEREE STATION EQUIPMENT COSTS

EQUIPMENT	FTP CAPABILITY	MINIMUM SYSTEM (LOAD/DIAG.)
Constant Volume Sampler (CVS)	$12,000	
CVS, Calibration Equipment	2,000	
Sampler System	5,400	
Dynamometer with road load inertia weights	39,000	$16,453
Driver's Aid	5,000	5,000
Cooling fan	650	
Analyzer bench	125,000	16,000
Isolated power for analyzer	3,000	
AC regulators	500	
Gases	8,000	870
Miscellaneous-barometer, wet & dry bulb	8,850	850 Computer
FTP equipment (soak area)	12,000	
Total	$221,400	$39,175

B. CORRELATION CAR

In addition to the regularly scheduled calibration checks, correlation vehicles could be used to further standardize the station-to-station equipment complements. An emission test performed using a highly standardized correlation vehicle would provide a quality check on the entire analytic system (i.e.; analyzer, sample collection system, tachometer, and inspection personnel).

The costs of a correlation vehicle is presented in Table 6-2.

Table 6-2. CORRELATION VEHICLE COST PER UNIT

1. Vehicle: 360 CID engine, automatic transmission	$ 5,000.00
2. Propane conversion (Emco)	1,000.00
3. Take off power items (power steering brakes, windows, air conditioning, etc.) and remove vacuum advance and alternator	500.00
4. Install recorder and sensing device to record fuel temperature, carburetor and engine rpm	1,500.00
5. Install torque meter	500.00
6. Trailer	1,200.00
7. Hitch	120.00
Total	$9,820.00

C. TAMPERING CHECK

Tampering check as a function of vehicle inspection. This problem is presented in Appendix F. The major focus on tampering would be for NO_x. This involves checking for:

- System hoses missing
- Steel ball in vacuum hose
- Top of EGR valve is dimpled reducing stroke; thereby the vacuum status
- Drilled holes for air access
- Coolant thermostat switch alteration
- Vacuum amplifier modification
- Vacuum line notched or cut

This check can be accomplished in approximately 30 seconds using visual and vacuum checks.

D. DIESEL VEHICLES

Due to visible smoke emissions, the diesel engine is widely blamed for much of the atmospheric pollution. However, the medically harmful pollutants such as carbon monoxide, benzopyrene, and aldehydes are emitted only in low concentrations, while the oxides of nitrogen, though by no means negligible, are present in much lower proportions than in gasoline engines. However, black diesel exhaust smoke is readily noticeable and is a potential safety hazard. Therefore, many studies have introduced legislation to limit such diesel smoke. These limits are checked with opacity measurements. Diesel exhaust odor, a further sign of malfunctioning, is another area of concern.

1. Constituents in Diesel Engine Exhaust Emissions

- **Black Smoke** (Unburned Carbon Particles)
  Unburned carbon, appearing as visible black smoke, is a clear indication of inefficient operation; as such, its elimination is a matter

of personal as well as public interest to diesel vehicle operators. The composition of exhaust smoke has been reported between 75 and 95 percent carbon (Ref. 10) showing significant variation with engine loading (Ref. 11). Particle size varies in the 0.1-0.3 μm range with smaller particles predominating. Particles in this size are problems in personal health.

- White Smoke

  A fine mist of partly vaporized fuel and water droplets is often produced in "cold-start" conditions or on misfire (Ref. 12). This is white smoke and is a powerful irritant due, in part, to accompanying aldehydes in the exhaust gases. Fortunately it is of short duration and is of little importance in normal driving schedules. Thus, one can distinguish between "hot" smoke (black) and "cold" smoke (white).

- Blue Smoke

  Although "white" smoke and (particularly) black" smoke have attracted wide attention, less is known about "blue" smoke (Ref. 12). This does not become visible until several feet from the exhaust and is probably the result of a cooling and (ultimately) condensation process. Precipitation of the droplets in blue smoke yields a dark amber liquid of the viscosity of light lube oil. Mass spectrometric analysis has shown this to be a mixture of hydrocarbons. Blue smoke droplets are of much smaller diameter than those of white smoke or the particles in black smoke. They represent a particular fraction of the unburned fuel in the exhaust, viz. that fraction which will condense in the colder conditions some feet away from the exhaust pipe. It is heaviest at medium load, the maximum emission occurring at 40 percent rated load with straight-run fuels, at 60 percent with cracked fuel. At higher engine speeds the maximum blue smoke emission occurs at lower loads, this shift being related to exhaust temperature.

- **Odor**

  Diesel exhaust odor, although somewhat unpleasant, is not of itself dangerous, except in confined situations. However, as symptomatic of some pollution "odor" is now regulated by the State of California. There seems to be no direct correlation between odor and pollutants; thus odor and irritant intensity have to be assessed by panel estimates. In comparative studies it has been assumed that aldehydes and oxides of nitrogen are the most probably odoriferous constituents. Minor sources of odor, such as organic peroxides and acids are unlikely to be present in sufficient quantity to contribute to noticeable levels.

- **Other Pollutants**

  The pollutants arousing most concern in spark-ignition engines have been shown to be present in relatively insignificant quantities in the case of diesel engines. Figure 6-3 shows the concentration of some pollutants related to air/fuel ratio (Ref. 13). Carbon content is seen to increase rapidly at higher air/fuel ratio than carbon monoxide. (The range of values shown covers a wide range of production model engines.) .Furthermore, concentration of 3.4-benzpyrene is of negligible importance at acceptable air/fuel ratios, and measurable quantities of nitrogen oxides are not detected until fuel delivery rates are nearly twice normal values, so that pollution from either source is unlikely to be important. Carbon, emitted as black smoke, remains the most serious pollutant.

The diesel engine because of its high combustion ratio, better utilizes the calorific value of injection fuel, so it needs less fuel than a gasoline engine to develop the same horsepower, Figure 6-4 (Ref. 14).

2. Light-Duty Diesel-Powered Vehicles

The emissions of an uncontrolled diesel engine is presented in Appendix G. In its uncontrolled form (i.e., pre-1973), the diesel engine emits 1.1 gm/km (1.7 gm/mi) carbon monoxide, and 0.29 gm/km (0.46 gm/mi) hydrocarbons. This

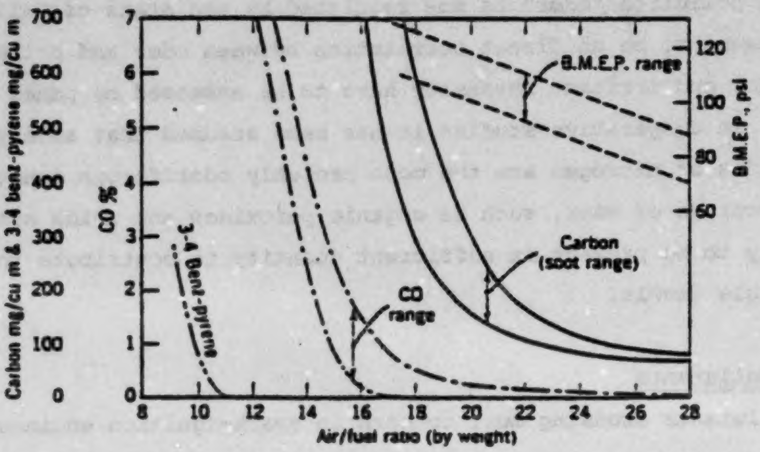


Figure 6-3. DIESEL ENGINE EXHAUST GAS CONSTITUENTS

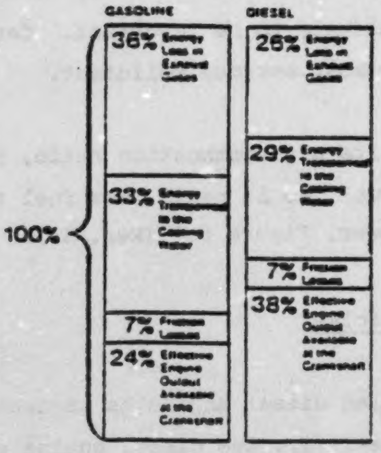

GASOLINE
DIESEL
100%
36% Energy Loss in Exhaust Gases
33% Energy Transferred to the Cooling Water
7% Friction Losses
24% Effective Engine Output Available at the Crankshaft
26% Energy Loss in Exhaust Gases
29% Energy Transferred to the Cooling Water
7% Friction Losses
38% Effective Engine Output Available at the Crankshaft

Figure 6-4. COMPARATIVE ANALYSIS DIESEL VERSUS GASOLINE ENGINE MERCEDES-BENZ DATA

is considerably less than comparable controlled gasoline engines with 1.7 gm/km carbon monoxide and 0.46 gm/km hydrocarbons.

The Federal emissions standards for 1978 light-duty vehicles as set forth in the Federal Register Title 40, Paragraph 86.078-8 does not differentiate between light-duty gasoline or light-duty diesel engines. The standards set forth are:

- Hydrocarbons - 0.41 grams per vehicle mile
- Carbon Monoxide - 3.4 grams per vehicle mile
- Oxides of Nitrogen - 0.4 grams per vehicle mile

Comparing these 1978 standards to the emission values for the pre-1973 uncontrolled vehicle, one finds that the diesel engine without controls meets the 1978 standard, except in the NO_x emissions.

An opacity standard for LDV smoke emissions should be defined as in the emissions standards for 1978 diesel heavy-duty vehicles.

Statistics on the number of light-duty diesel vehicles (LDDV) as obtained from the manufacturer's sales personnel, relating to the sales of light-duty vehicles is as follows:

Oldsmobile

- Diesels are 12.2 percent of Oldsmobile sales
- Oldsmobile has about 8.75 percent of the sales market

Mercedes-Benz

- Diesels are 65 percent of the Mercedes vehicle sales
- Mercedes-Benz sales on an allocated basis 53,000 vehicles in the U.S.
- Mercedes-Benz has about 0.5 percent of the market

Volkswagen (VW)

- Volkswagen is planning to market diesels in Rabbit and Dasher models.
- Sale forecast is about 60,000 vehicles per year.

On the basis of the above statistics, it is assumed that the light-duty diesel engine has 1.3 percent of the vehicle market in the United States.

It is evident that a well designed diesel engine, regularly maintained and sensibly operated without overloading will produce very little HC/CO or smoke emissions.

3. Heavy-Duty Diesel-Powered Vehicles

Heavy-duty diesel-powered vehicles (HDDV) as compared with its counterpart in the gasoline-powered HD engine, feature low pollution power plants. The emissions factors for the heavy-duty diesel-powered vehicles (pre-1973) are presented in Appendix H. In the pre-1973 vehicles, the HDDV CO emission factors were 28.7 gm/mi (truck) and 21.3 gm/mi (bus); 4.6 g/mi (truck) and 4.0 (bus) for HC; and 20.9 gm/mi (truck) and 21.5 gm/mi (bus) for NO_x. The emission factors for HDGV were 188 gm/mi CO, 13.6 g/mi HC, and 12.5 g/mi NO_x. It is evident that the diesel emissions are considerably lower.

The EPA in 1979 promulgated new standards for the 1980 heavy-duty diesel engines. These standards are:

- Hydrocarbons - 1.5 grams per brake horsepower
- Carbon monoxide - 25 grams per brake horsepower
- Hydrocarbons plus oxides of nitrogen - 10 grams per brake horsepower hour

Or the following standards

- Hydrocarbons plus oxides of nitrogen - 5 grams per brake horsepower hour
- Carbon monoxide - 25 grams per brake horsepower hour

The opacity of smoke emissions from new 1979 and later model-year diesel heavy-duty engines shall not exceed:

- 20 percent during the engine acceleration mode
- 15 percent during the engine lugging mode
- 50 percent during the peaks in either mode

The new standards are more stringent on emissions then the 1972 noted values. The corresponding levels are difficult to interpolate because of the certification test mode applied is in brake horsepower readings. To establish an I/M program having gas emissions testing it will be necessary to develop short tests that would correlate to the FTP for heavy-duty diesel. At present, the test would include only opacity checks. This ensures that the vehicle is operating in a satisfactory air/fuel ratio range. The test could be measured under "free acceleration" conditions that is, full throttle in neutral gear to give three successive similar maximum smoke readings.

E. FIRST-YEAR VEHICLES

Vehicle stress inducement relative to time is presented in Figure 6-5. This figure notes three failure rate regions. These regions are:

- The green engine region (t_d) (break-in region) wherein the vehicle has a failure rate slightly higher then the stabilized region.
- Stabilized region (t_u) where the failure rate is constant.
- t_u region (wear-out region) has a continuously increasing failure rate.
- t_o region has an increasing slope identifying high rate of failure. This is the area of gross polluters.

In the majority of reported cases, new vehicle owners (i.e., first year) returned their vehicles to the dealers for servicing within the warranty

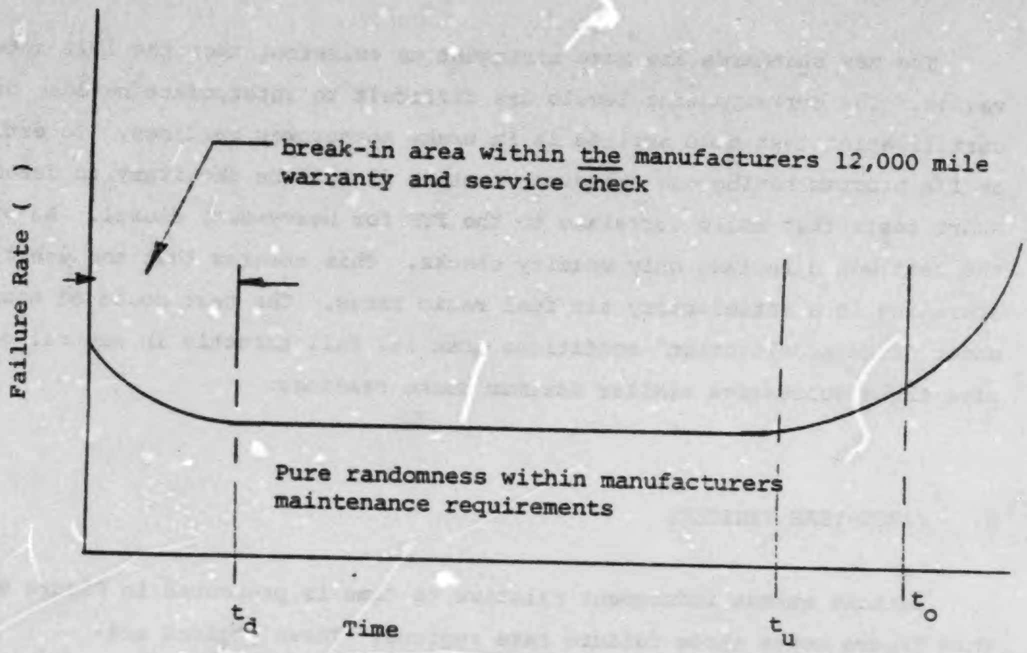


Figure 6-5. FAILURE RATE REGION

period of 12,000 miles. This servicing would provide the necessary maintenance and repairs resulting in minimum emissions.

A California CVS 75 study (unpublished) performed in 1976 on 159 LDVs and 21 LDTs resulted in the following conclusions.

- "Closely" maintained vehicles were significantly lower in CO emissions.
- Failure rates were high on only one component--the EGR valve. The EGR valve becomes plugged with carbon residues because of tampering.
- Of the 105 1976 vehicles, 3 vehicles failed because of HC per CVS 75 test requirements and not per short test (Figure 6-6). The repaired vehicles were within emission standards.
- Of these 1976 vehicles, only 11 failed the CO test under CVS 75 testing. Seven would have failed a short test because of the lack of required maintenance, that is, adjustment of carburetor or timing (see Figure 6-7).

A review of Figures 4-3 and 4-4 of Section 4 would identify long- and short-term vehicle deterioration.

It is generally accepted that vehicle emissions increase with time, and that there is a corresponding change in fuel consumption as well; however, it is also concluded that if there were no inspection and maintenance program there would be little deterioration the first year. An SCI study showed that, after repairs, emissions remained generally low for 6 to 9 months and then increased to pre-repair levels after about 1 year (Ref. 15). It is assumed that each new car is in satisfactory repair as it leaves the dealer's show room. Presumably, vehicle emissions will remain at satisfactory levels for 1 year thereafter. It is to be noted that the manufacturers are subject to average quality level audit of all new 49 state cars. Thus, the quality setting for emissions on new cars are normally to FTP standards or less.

The number of new in-use vehicles is, per the 49 state average, 7.5 percent. The HC reductions would be negligible the first 6 months of vehicle use. The Mobile 1 Program uses a 0.30 gm/mi emissions factor for LDV. The EPA standard is 0.41 gm/mi.

Figure 6-6.
Frequency Distribution of CVS-75 HC
Emissions for 1976 Passenger Cars

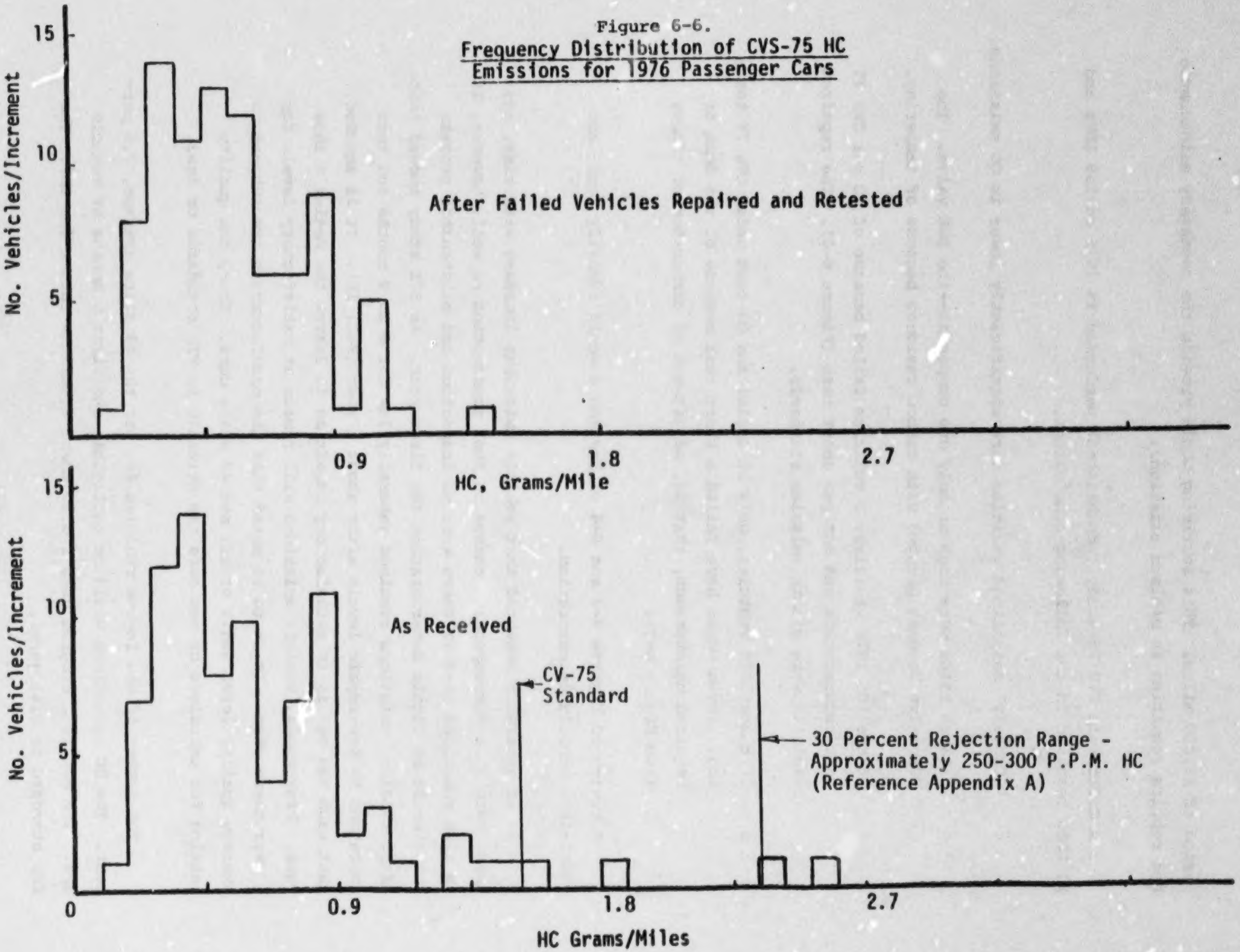
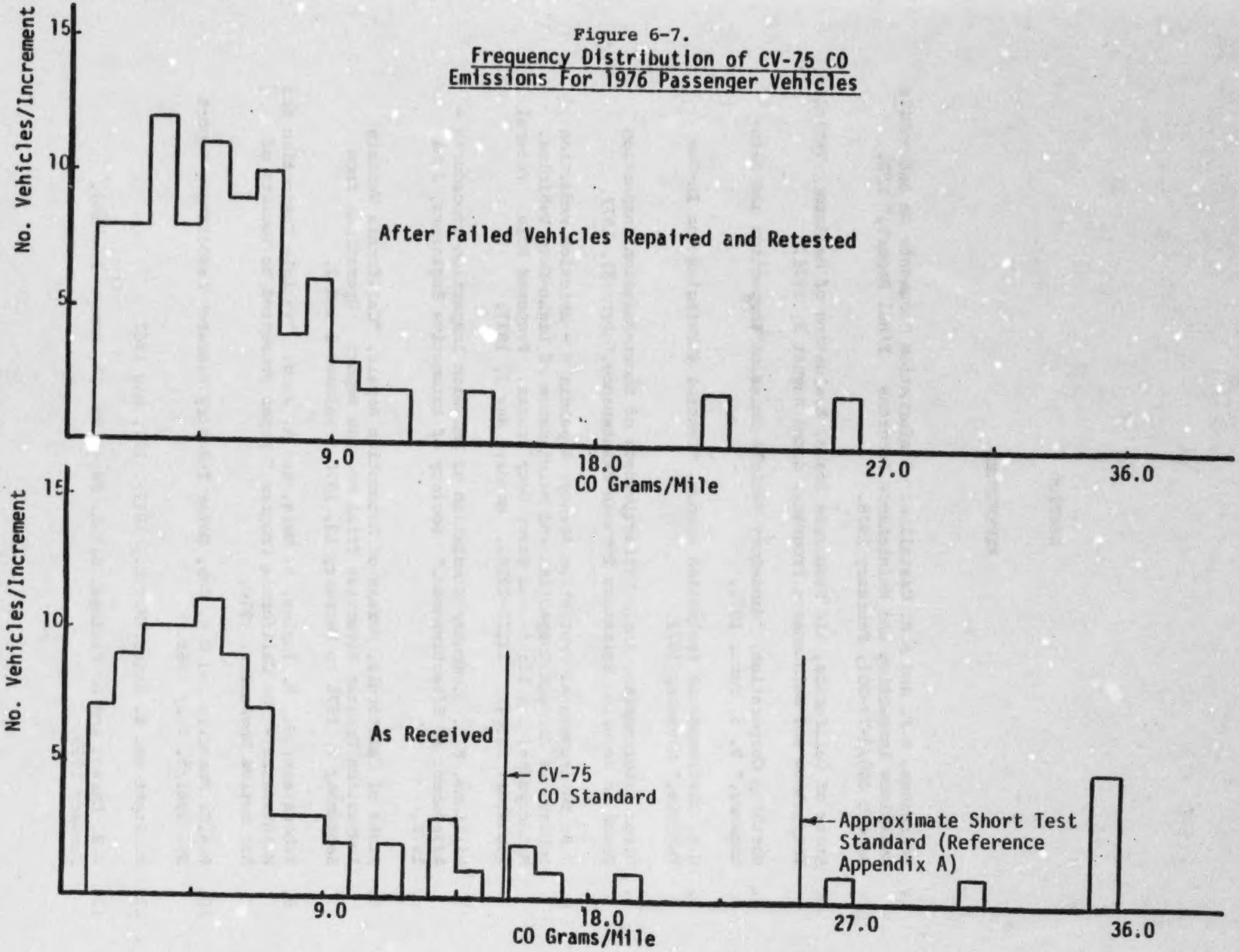


Figure 6-7.
Frequency Distribution of CV-75 CO Emissions For 1976 Passenger Vehicles



Section 7

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Appendix A

MEMO FROM THE UNITED STATES EPA TO REGIONAL EPA ON I/M POLICY

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ANN ARBOR, MICHIGAN 48105

OFFICE OF
AIR AND WATER PROGRAMS

JUL 17 1978

RECEIVED
JUL 19 1978
Air Programs Branch
AHMD US EPA Region V

SUBJECT: Inspection/Maintenance Policy

FROM: David G. Hawkins, Assistant Administrator
for Air and Waste Management

MEMO TO: Regional Administrators, Regions I - X

As you know, the Clean Air Act Amendments of 1977 set forth specific requirements for the implementation of motor vehicle inspection/maintenance (I/M) programs. Attached is a policy paper indicating what EPA will consider a minimally acceptable program wherever I/M is required by the Act. It should aid your efforts to provide for adequate I/M submissions for the State Implementation Plan (SIP) revisions of January 1, 1979. Please continue to contact me if problems in I/M implementation develop.

cc: Air and Hazardous Materials Division
Directors, Regions I, III - X
Environmental Programs Division Director,
Region II
Air Programs Branch Chiefs, Regions I - X

JL

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Policy for the Development and Implementation of Inspection/Maintenance Programs

The Clean Air Act Amendments of 1977 provide new direction for the development and implementation of motor vehicle inspection/maintenance (I/M) programs. If states are not able to demonstrate attainment of the standards for oxidant (Ox) or carbon monoxide (CO) by December 31, 1982, a specific schedule for the implementation of I/M must be included in the State Implementation Plan (SIP) revisions of January 1, 1979 for the plan to meet the requirements of Section 172. The general requirements for the I/M programs are set out in a February 24, 1978 memorandum from the EPA Administrator to the Regional Administrators (reprinted in the Federal Register on May 19, 1978, 43 F.R. 21673). The requirements, for these programs, are explained in more detail below.

A. I/M SIP Revision Development and the January 1, 1979, Submittal

In producing an I/M SIP revision, the states should provide for:

1. an analysis of the benefits and costs of the program;
2. a public information effort;
3. a legislative proposal; and
4. a schedule for I/M implementation.

A copy of suggested steps for development of the SIP revision is attached (Attachment 1). Before the January 1, 1979 submittal, the SIP revision must be adopted by the state air pollution control board or agency head as appropriate. As a part of the SIP revision submittal itself, there must be a commitment by the Governor to implement the I/M program according to the schedule submitted.*

---

*Sections 172(b)(7) and (10) provide that the plan revisions required for nonattainment areas shall —

(7) identify and commit the financial and manpower resources necessary to carry out the plan provisions required by this subsection; [Emphasis added]

and shall —

(10) include written evidence that the state, the general purpose local government or governments, or a regional agency designated by general purpose local governments for such purpose, have adopted by statute, regulation, ordinance, or other legally enforceable document, the necessary requirements and schedule and timetables for compliance, and are committed to implement and enforce the appropriate elements of the plan; [Emphasis added]

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These plan elements should be prepared in accordance with the guidance on pages 186-188 of the Compilation of Presentations prepared by EPA's Office of Air Quality Planning and Standards (OAQPS) for the "Workshops on Requirements for Nonattainment Area Plans" February -March 1978 (pages 213-220 in the April 1978 edition).

B. The I/M Implementation Schedule

The specific items listed below must be included as a part of the States' I/M implementation schedules with specified dates for implementation of each item. The stringency planned for the program and other factors affecting the potential for emission reductions should also be indicated. Additional items if necessary because of local factors may be required by USEPA Regional Offices.

1. Initiation (or continuation) of public information program including publicizing the I/M program in the media, meeting and speaking with affected interest groups, etc.
2. Preparation of a draft legislative package and submittal of legislation package to legislature if additional legislative authority is needed.
3. Certification of adequate legal authority by appropriate state official.
4. Initial notification of garages explaining program and schedule of implementation.*
5. Development and issuance of RFPs.*
6. Award to contractor(s).*
7. Initiation of construction of facilities.*
8. Completion of construction of facilities.*
9. Adoption of procedures and guidelines for testing and quality control including emission analyzer requirements (and licensing requirements for private garages, if applicable*).
10. Notification of and explanation to garages of actions in step 9.*

11. Completion of equipment purchase and delivery of equipment.

12. Development and adoption of cutpoints.

13. Initiation of hiring and training of inspectors or licensing of garages.*

14. Initiation of introductory program (voluntary maintenance with either voluntary or mandatory inspection) if not previously initiated.

15. Initiation of mechanics training and/or information program.

16. Initiation of mandatory inspection.

17. Initiation of mandatory repair for failed vehicles.

If certification of adequate legal authority occurs after January 1979, the States may modify previous commitments to implement and enforce the elements of the schedule to conform to the legal authority.** These modifications will be approved by the EPA Regional Offices and must be consistent with the Administrator's February 24, 1978, policy memorandum. The documents should be submitted to the EPA Regional Offices for inclusion in the SIP revisions already submitted by January 1, 1979. Any necessary adjustments to the schedule may be made at this time but must be approved by the EPA Regional Offices.

C. Authority to Implement I/M

Normally, adequate legal authority to implement a SIP revision must exist for a revision to be approved. Where a legislature has had adequate opportunity to adopt enabling legislation before January 1, 1979, the Regional Administrator should require certification that adequate legal authority exists for I/M implementation by January 1, 1979. However, for many states there will be insufficient opportunity to obtain adequate legal authority before their legislatures meet in early 1979. Therefore, a certification of legal authority for the implementation of [illegible] in these states must be made no later than June 30, 1979. An extension to July 1, 1980, is possible, but only when the state can demonstrate that (a) there was insufficient opportunity to conduct necessary technical analyses and/or (b) the legislature has had no opportunity to consider any necessary enabling legislation for inspection/ maintenance between enactment of the 1977 Amendments to the Act and June 30, 1979. Certification of adequate legal authority, or other evidence that legal authority has been adopted, must be submitted to the EPA Regional Offices to be included in the SIP revision already submitted. Failure to submit evidence of legal authority by the appropriate deadline will constitute a failure to submit an essential element of the SIP, under Sections 110(a)(2)(I) and 176(a) of the Act.

---

*Dependent on type of system chosen (state-run centralized, contractor centralized, or decentralized).

**See footnote on page 1.

Prior to the respective deadlines for initiating mandatory inspection and mandatory repair of failed vehicles, the state, local government, or regional agency should adopt whatever legally enforceable requirements are necessary to ensure that vehicles are not used unless they comply with the inspection/maintenance requirements. Written evidence of adoption of these requirements should be submitted to the EPA Regional Offices, to be included in the SIP revision already submitted by January 1, 1979.*

D. I/M Implementation Deadlines

Implementation of I/M "as expeditiously as practicable" shall be defined as implementation of mandatory repair for failed vehicles no later than two and a half years after passage of needed legislation or certification of adequate legal authority for new centralized systems and one and a half years after legislation or certification for decentralized systems or for centralized systems which are adding emission inspections to safety inspections. For the normal legislation deadline of June 30, 1979, new centralized programs must start by December 31, 1981, and all others must start by December 31, 1980. For the case of the latest possible legislation date, July 1, 1980, this means that a new centralized program must start by December 31, 1982, while all other programs must start by December 31, 1981. Where I/M can be implemented more expeditiously, it must be. Each state implementation schedule must be looked at individually to determine if it is as expeditious as practicable. Implementation dates ordered by courts, if earlier than these dates, take precedence.

E. Geographic Coverage

I/M should focus on metropolitan areas and should include the entire urbanized area and adjacent fringe areas of development. Boundaries of the area affected may be adjusted if an equivalent emission reduction is achieved. For urbanized areas of 200,000 population or greater which need I/M to obtain an extension of the 1982 attainment date, full mandatory I/M must be implemented by the deadlines indicated above. Statewide programs are encouraged, especially for those states which are small and highly urbanized.

It should be emphasized that all nonattainment areas must have SIPs which are adequate to attain and maintain the National Ambient Air Quality Standards (NAAQS) by 1982 or by no later than 1987 should an acceptable nonattainment demonstration be made. For areas under 200,000, EPA will not at this time automatically require I/M schedules in 1979 as a condition for SIP approval or an extension. However, areas under 200,000 still have to attain and maintain NAAQS as expeditiously as practicable, and I/M is encouraged as a means of helping to provide for an adequate SIP. EPA will review the need for I/M in areas under 200,000 after the 1979 SIP revisions are submitted, and will consider additional requirements at that time.

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*See footnote on page 1.

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F. Emission Reductions Required for I/M

I/M programs must produce at least a 25 percent reduction in light duty vehicle (LDV) exhaust emissions of hydrocarbons and a 25 percent reduction in LDV emissions of carbon monoxide by December 31, 1987, compared to what emissions would be without I/M on the basis of the most recent motor vehicle emission factors. However, the choices of stringency factor to be used and other actions affecting the potential for emission reduction should be made by the states. States should of course be encouraged to develop programs which produce more emission reduction when possible. The final revision to Appendix N (40 C.F.R., Part 51) when promulgated (along with its minimum program requirements) should be used to determine if the program described in the implementation schedule will meet the minimum 25 percent CO/25 percent HC criterion. Should a program not need to be this stringent to attain and maintain the NAAQS by 1982, the I/M program need be only as stringent as needed to assure conformity with NAAQS. Should a state want to emphasize control of one particular pollutant at the expense of the other, the plan for such an I/M program must be submitted to the appropriate EPA Regional Office for approval.

G. Minimum Program Requirements

In addition to the emission reduction requirement above, all I/M programs must:

1. provide for regular periodic inspections of all vehicles for which emission reductions are claimed;*
2. provide for maintenance and retesting of failed vehicles to provide for compliance with applicable emission standards;
3. prohibit registration or provide some equally effective mechanism to prevent vehicles which do not comply with the applicable exhaust emission requirements from operating on public roads;
4. provide for quality control regulations and procedures for the inspection system including:

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*Random roadside checks, while a useful addition to an I/M program, are not an acceptable substitute for regular periodic inspections.

a. minimum specifications for emission analyzers

b. required calibrations of all types on analyzers and

c. minimum record keeping;

5. provide for either a mechanics training program or a program to inform the public of service establishments with approved emission analyzers; and

6. inform the public of the reason for the I/M program plus the locations and hours of inspection stations.

Decentralized systems must also comply with the following requirements.

1. All official inspection facilities must be licensed. Provisions for the licensing of inspection facilities must insure that the facility has obtained, prior to licensing, analytical instrumentation which has been approved for use by the appropriate state, local, or regional government agency. A representative of the facility must have received instructions in the proper use of the instruments and in vehicle testing methods and must have demonstrated proficiency in these methods. The facility must agree to maintain records and to submit to inspection of the facility. The appropriate government agency must have provisions for penalties for facilities which fail to follow prescribed procedures and for misconduct.

2. Records required to be maintained should include the description (make, year, license number, etc.) of each vehicle inspected, and its emissions test results. Records must also be maintained on the calibration of testing equipment.

3. Summaries of these inspection records should be submitted on a periodic basis to the governing agency for auditing.

4. The governing agency should inspect each facility periodically to check the facilities' records, check the calibration of the testing equipment and observe that proper test procedures are followed.

5. The governing agency should have an effective program of unannounced/unscheduled inspections both as a routine measure and as a complaint investigation measure. It is also recommended that such inspections be used to check the correlation of instrument readings among inspection facilities.

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6. The governing agency should operate a "referee" station where vehicle owners may obtain a valid test to compare to a test from a licensed station. At least one "referee" station must be present in each I/M metropolitan area.

Attachment 1

Suggested I/M Milestones

1. Complete plan for preparing and implementing I/M SIP revision including:
    a. technical analysis
    b. public information program
    c. development of necessary legislation
    d. development of I/M implementation schedule.
2. Complete technical analysis including:
    a. emission reduction benefits
    b. fuel economy benefits
    c. costs.
3. Complete elements of a continuing public information program including:
    a. further publicity concerning oxidant (and/or carbon monoxide) episodes
    b. meeting with and speaking to affected interest groups (including the public and public officials)
    c. news releases.
4. Complete development of legislative proposals.
5. Complete development of I/M implementation schedule.
6. Receive approval of I/M, including implementation schedule, from air pollution control board or agency head as applicable and introduce into state legislature.
7. Submit SIP revision for I/M, including implementation schedule, to EPA (due no later than January 1, 1979).
8. Obtain legal authority needed to implement I/M (required by July 1, 1979, with some exceptions allowed until July 1, 1980).

Appendix B

EMISSION CREDITS GIVEN IN THE CODE OF FEDERAL REGULATIONS

Appendix N - Emission Reductions Achievable Through Inspection, Maintenance of Light-Duty Vehicles, Motorcycles, and Light- and Heavy-Duty Trucks.

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Appendix B

EMISSION CREDITS GIVEN IN THE CODE OF FEDERAL REGULATIONS

ENVIRONMENTAL PROTECTION AGENCY

[40 CFR Part 51]

[FRL 703-4]

APPENDIX N—EMISSION REDUCTIONS ACHIEVABLE THROUGH INSPECTION AND MAINTENANCE OF LIGHT DUTY VEHICLES, MOTORCYCLES, AND LIGHT AND HEAVY DUTY TRUCKS

AGENCY: Environmental Protection Agency.

ACTION: Proposed rule.

SUMMARY: This Appendix presents estimates of potential emissions reduction benefits which, in the judgment of the Administrator, are likely to be achievable through the application of a properly structured and managed inspection/maintenance (I/M) program. Estimates of emission reductions available through retrofit programs, formerly contained in Appendix N, have been deleted. Inspection/Maintenance program effectiveness is given as a function of the level of technology, the stringency of emission standards, the length of program operation, and the adequacy of mechanic training. Basic program requirements are outlined for both the centralized and decentralized program concept. Attachment 1 provides a discussion of the modeling techniques utilized to generate the emission reduction estimates, while Attachment 2 provides computational examples illustrating the usage of Appendix N.

FOR FURTHER INFORMATION CONTACT:

John O. Hidinger, Director, Office of Transportation and Land Use Policy (AW-445) U.S. Environmental Protection Agency, 401 M Street SW., Washington, D.C. 20460 (202-755-0460).

ADDRESS: Submittal of Comments: Comments upon Appendix N are requested. Such comments should be directed to the individual below and postmarked no later than August 1, 1977.

Dated: April 19, 1977.

DOUGLAS M. COSTLE,
Administrator.

In Part 51, of Title 40, Code of Federal Regulations, Appendix N is revised to read as follows:

APPENDIX N—EMISSION REDUCTIONS AND ACHIEVABLE THROUGH INSPECTION AND MAINTENANCE OF LIGHT DUTY VEHICLES, MOTORCYCLES, AND LIGHT AND HEAVY DUTY TRUCKS

AUTHORITY: Section 301(a) of the Clean Air Act as amended by section 15(c)(2) of Pub. L. 91-604, 84 Stat. 1713; 81 Stat. 504 (42 U.S.C. 1857g(a)).

1. *Introduction.* This Appendix presents estimates of the potential emissions reduction benefits which, in the judgment of the Administrator, are likely to be achievable through the application of a properly structured and managed inspection/maintenance (I/M) program. Since the publication of the original Appendix N, new data obtained and experience gained from operating programs have shown the necessity for a revision to certain portions of this document. In addition, estimates of emission reductions available through retrofit programs, formerly contained in Appendix N, have been deleted. Retrofit guidance will be placed in a separate appendix consistent with a format to be followed for other strategies.

To the extent possible, estimates in this Appendix are based on empirical data. However, lack of data in several areas has necessitated extrapolation of empirical data using modeling techniques based on sound engineering judgment. A description of these modeling techniques is contained in Attachment 1. As new data become available, or as predicted extrapolations change, this Appendix will be revised and amended accordingly.

Several definitions have been modified to reflect their intended meaning. Most important, "initial failure rate" has been redefined as a "stringency factor." Hopefully, this new definition will dispel past misapprehension concerning the "initial failure rate" concept. In addition, the idle test has been slightly redefined to reflect actual idle emission testing currently being used.

The minimum requirements of an I/M program are defined. Those programs which are contemplating the use of a private garage I/M program should note the special requirements necessary to obtain the basic emission reduction credits.

Emission reductions for light duty vehicles are estimated not only for the first year of an I/M program but also for subsequent years since modeling has shown that the reduction benefits can increase with time. Additional emission reductions are estimated for those programs which include twice-a-year inspection and special mechanic training. Estimates of emission reductions resulting from I/M programs for light-duty trucks, heavy-duty trucks, and motorcycles are also given.

Certification data and recent surveillance data indicate that I/M effectiveness may be greater (especially for carbon monoxide) for catalyst equipped in-use vehicles than for pre-catalyst vehicles. By the time many I/M programs are fully implemented, catalyst-equipped vehicles will dominate the vehicle mix. Estimates are therefore given for the effectiveness of I/M on such vehicles, despite the limited data base at the present time.

Tables 1 through 5 summarize the emission reductions obtainable from I/M pro-

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grams. The actual benefit obtained by any state or region implementing a well-designed program may exceed the emissions reductions listed. Such higher reductions, however, would have to be shown through an adequate source surveillance study.

2. *Definitions.* a. "Cutpoint" means the level of emissions which discriminates between those vehicles requiring emission-related maintenance and those that do not.

b. "Federal Test Procedure" (FTP)—A sequence of testing utilized by the Agency to measure vehicle exhaust emissions over a typical urban driving cycle.

c. "Heavy-duty vehicle" means for the purpose of this Appendix, a gasoline fueled motor vehicle whose GVW is greater than 8,500 pounds.

d. "Idle emissions test" or "idle test" means a test procedure for sampling exhaust emissions which requires operation of the engine in the idle mode only. At a minimum, the idle test should consist of the following procedure carried out on a fully warmed-up engine: a measurement of the exhaust emission concentrations for a period of time of at least 15 seconds, shortly after the engine was run at 2,000 to 2,500 rpm with no load for approximately 60 seconds.

e. "Inspection/maintenance" means a strategy to reduce emissions from in-use vehicles by identifying vehicles that need emissions-related maintenance and requiring that such maintenance be performed.

f. "Light-duty vehicle" means a passenger car or passenger car derivative capable of seating 12 persons or less.

g. "Light-duty truck" means, for the purpose of this Appendix, a motor vehicle designed primarily for the transportation of property, or the derivation of such a vehicle, whose GVW is 8500 pounds or less.

h. "Load emissions test" or "loaded test" means a test procedure for sampling exhaust emissions which exercises the engine under loading by use of a chassis dynamometer to stimulate actual driving conditions. As a minimum requirement, the loaded test must include running the vehicle and measuring exhaust emissions at two speeds and loads other than idle.

i. "Motorcycle" means for the purpose of this Appendix, a two-wheeled motorized vehicle designed to transport persons or property on a street or highway.

j. "Stringency factor" is a measure of the rigor of a program based on the estimated fraction of the vehicle population whose emissions would exceed cutpoints for either or both carbon monoxide and hydrocarbons were no improvements in maintenance habits or quality of maintenance to take place as a result of the program.

k. "Tampering" means, for the purpose of this Appendix, rendering inoperative, or intentional misadjustment of any motor vehicle device or element of design intended to control exhaust emissions.

l. "Technology I" means the general type of exhaust emission control technology utilized on all light-duty vehicles subject to pre-1975 Federal emission standards.

m. "Technology II" means the general type of exhaust emission control technology utilized on light-duty vehicles subject to 1975 and later model year federal exhaust emission standards.

3. *Emission reductions for light-duty vehicles.* Tables 1 through 4 list emission reductions for light-duty vehicles that can be achieved through properly structured and managed programs of inspection/maintenance and accompanying mechanic training. See Attachment 1 and 2 for a description of the derivation of these credits and for computational examples of the use of the tables.

a. *First year program credits.* The following first year credits are applicable to both idle and loaded tests.

TABLE 1.—*First year of program credits*

Stringency factor	HC (percent)		CO (percent)	
	Technology I	Technology II	Technology I	Technology II
0.10	1	1	3	5
.20	5	3	8	20
.30	7	9	13	28
.40	10	16	19	33
.50	11	24	22	37

b. *Subsequent years program credit.* The following additional (to Table 1) credits are applicable to vehicles which have undergone more than one inspection by the beginning of the calendar year of interest. These credits are not applicable to programs having inspection intervals of longer than one year. For a model year group of vehicles, the appropriate credit is selected on the basis of the specific number of inspections that the group has incurred by the beginning of the calendar year of interest. The credit is then added to the appropriate first year credit above. Credits are applicable to both technology level cases, to the idle and loaded tests, and to all stringency factor programs.

TABLE 2.—*Subsequent years program credit*

Number of inspections	Additive credit	
	HC (percent)	CO (percent)
2	7	6
3	14	13
4	20	19
5	25	23
6	30	27
7	33	30
8 or more	36	35

c. *Semi-annual I/M program credit.* A credit of 0.2 percent per subsequent semi-annual inspection may be added, up to 15 times, to the first year (Table 1) credits for those programs requiring semi-annual inspection. This credit is applicable at all stringency factors for both HC and CO, idle and loaded tests, and both technology levels.

d. *Mechanic training program credit.* The following additional credits may be taken for the presence of an adequate program of mechanic training.[1] Table 3 provides the basic credits for mechanic training, while Table 4 lists the appropriate credits to be added to Table 3 credits for subsequent years of program operation. The sum of Table 3 and 4 credits is then to be added to the basic credit computed from Tables 1 and 2.

TABLE 3.—*Mechanic training first year credits*

Stringency factor	Technology I		Technology II	
	HC (percent)	CO (percent)	HC (percent)	CO (percent)
0.10	1	5	3	7
.20	3	7	5	10
.30	4	9	4	10
.40	6	8	1	7
.50	7	7	1	5

TABLE 4.—*Mechanic training subsequent year credits*

Technology I

Stringency factor	Number of inspections			
	2		3 or more	
	HC (percent)	CO (percent)	HC (percent)	CO (percent)
0.10	3	3	15	18
.20	4	8	10	15
.30	6	5	9	9
.40	5	5	5	5
.50	3	2	3	2

Technology II

Stringency factor	Number of inspections—2 or more	
	HC (percent)	CO (percent)
0.10	10	4
.20	8	2
.30	2	1
.40	1	3
.50	1	1

The above Table 4 credits are applicable to vehicles which have undergone more than one inspection by the beginning of the calendar year of interest. For a model year group of vehicles, the appropriate credit is selected on the basis of the technology level of the vehicles, the number of inspections the vehicles have incurred by the beginning of the calendar year of interest, and the stringency factor of the I/M program. The credit is then added to the appropriate first year mechanic training credit (Table 3) and the result is added to the basic credit calculated from Tables 1 and 2. Credits are applicable to both the idle and the loaded test.

Inspection/maintenance approaches are expected to be applicable to heavy duty gasoline fueled trucks and motorcycles, as well as light duty vehicles.

a. *Emission reductions for motorcycles and light duty trucks.* The estimated emission reductions for this group of vehicles are the same as those given in Tables 1 through 4 for Technology I light duty vehicles.

b. *Emission reductions for heavy duty trucks.* Estimated emission reductions due to I/M for gasoline fueled heavy duty vehicles, using either an idle or loaded emissions test are as follows:

TABLE 5.—*Heavy duty vehicle I/M credit*[2]

Stringency factor	HC (percent)	CO (percent)
0.20	11.4	8.3
.30	12.3	9.2
.40	13.6	10.5
.50	17.2	12.0

Analysis of data (generated by the City of New York under EPA grant) on 65 trucks indicate that I/M is a potentially viable emission reducing strategy. The estimated emission reductions given above are based on these limited data. No data on the deterioration of trucks with or without I/M are available. The assumption utilized to develop Table 5 is that the average yearly effectiveness is one-half of the initial benefit achieved as a result of a tune-up.

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[1] The "adequacy" of a mechanic training program will, for the present, be determined on a case-by-case basis. Guidelines will be issued in the future if found to be feasible.

5. *Basic program requirements.* There are two basic types of operation which may be utilized for an I/M program, namely a centralized inspection system (government or contractor operated) and a decentralized inspection system (private commercial garages). In order to obtain full emission reduction benefits for either a centralized or decentralized inspection system, certain minimum requirements are established, which if not met, will result in assessed emission reductions lower than those listed in Tables 1 through 5 of this Appendix.

a. *Program requirements—Minimum* for all programs.

i. Provisions for regular periodic inspection (at least annually) of all vehicles for which emissions reductions are claimed.

ii. Provisions to ensure that failed vehicles receive the maintenance necessary to achieve compliance with the inspection standards. The basic method is to require that failing vehicles pass a retest following maintenance.

iii. Provisions for quality control. The reliability of the inspection system and equipment accuracy must be ensured. This will include routine maintenance, calibration and inspection of all I/M equipment, and routine auditing of inspection results.

b. *Minimum decentralized program requirements.* In order to receive the basic emission reduction benefits for a decentralized I/M program, the following requirements must be included in addition to provisions listed in Section 5(a).

i. Provisions for the licensing of inspection facilities which insure that the facility has obtained, prior to licensing, analytical instrumentation which has been approved for use by the appropriate governing agency. A representative of the facility must have received instructions in the proper use of the instruments and in vehicle testing methods. The facility must agree to maintain records, to collect signatures of operators whose vehicles have passed inspection, and to submit to inspection of the facility.

ii. Records required to be maintained should include the description (make, year, license number, etc.) of each vehicle inspected, and its emissions test results. Records must also be maintained on the calibration of testing equipment.

iii. Copies of these inspection records should be submitted on a periodic basis to the governing agency for auditing.

iv. The governing agency should inspect each facility at least once every 90 days to check the facilities' records, check the calibration of the testing equipment and observe that proper test procedures are followed.

v. The governing agency should have an effective program of unannounced/unscheduled inspections both as a routine measure and as a complaint investigation measure. It is also recommended that such inspections be used to check the correlation of instrument readings among inspection facilities.

c. *Motorcycle and heavy duty truck program requirements.* An acceptable I/M program for motorcycles and trucks must include the same provision specified in Section 5 for light duty vehicles. In addition, a source surveillance program, such as discussed in Section 6(c) is strongly recommended for any emission reduction estimates for motorcycles and heavy duty vehicles. The test procedures and program design for the evaluation of emission reductions should be reviewed in advance by EPA. The source surveillance program can include an assessment of emission deterioration at the option of a state. Without such an assessment, the assumption will be made that average yearly effectiveness is half of the initial benefit found.

6. *Additional Topics—Emission reductions.*

a. *Idle vs. loaded testing.* Although idle and loaded testing do not necessarily fail a mutually inclusive set of vehicles, latest available data indicate no overall difference in HC and CO emission reductions between the two tests. The available data do indicate that the loaded test can be more effective in reducing emissions than the idle test, but only if mechanics are extensively trained in the proper use of loaded test diagnostic information. For this reason, no additional credit is given for loaded mode testing. The loaded emission test does, however, have the potential to measure oxides of nitrogen from automobile emissions and can therefore be a valuable strategy in areas where there is a defined NOx problem.

b. *Tampering inspection.* Additional annual reductions in emissions can be achieved from a program of tampering inspection, in conjunction with emissions inspection. The amount of reduction credited will be a function of the sophistication and complexity of the tampering inspection and the training of the inspectors. To obtain these reductions there must be inspection and maintenance for tampering along with emission I/M. Any plans for tampering inspection should be reviewed with EPA in advance in order to estimate the potential benefits.

c. *Added benefits—source surveillance program.* It is possible that well designed and managed I/M programs will achieve greater reductions than those estimated in this Appendix. This can occur because deterioration rates and other factors may be different for specific geographic areas or because the service industry is doing a better job than estimated or because public maintenance habits improve significantly in response to the program.

To overcome the uncertainty associated with the above it is recommended that a source surveillance program be performed. The results of such a program would allow states and areas to update the emission reduction benefit for I/M as data become available. Such source surveillance studies can determine three key pieces of information: the initial reduction which vehicles can achieve in the first year of a program as a result of inspection and repair, the change in lifetime vehicle emission deterioration which can be credited to yearly inspections, and an accurate location specific emission inventory prior to I/M implementation.

An I/M program has the potential to change both the first year emission rate and the lifetime deterioration curve. Since a source surveillance program needs to be carefully designed to adequately evaluate benefits attributable to I/M, states are encouraged to review source surveillance study designs with regional EPA offices before beginning such programs. Technical guidance for program design and sizing of test samples will be available from EPA.

In the absence of a source surveillance program, states required to submit transportation control plans must use the estimates contained in this Appendix in the determination of emission reductions from inspection/maintenance programs. In addition, current and projected emission factors supplied by EPA must be used in these determinations, unless substantiating justification for other factors is provided.

At the present time, EPA is looking at the possibility of using short inspection tests to determine both percent emission reduction due to inspection and maintenance, and emission deterioration of vehicles over time. The ability to use short tests to determine percent emission reductions due to maintenance will depend upon the correlation of the short test with the Federal Test Procedure. Additional source surveillance implementation information will become available as current analyses are completed.

d. *Alternative approaches.* Maintenance-oriented programs that employ approaches other than emission testing may be capable of achieving emission reductions for in-use motor vehicles. Such approaches, including mandatory maintenance procedures and engine parameter inspection, will be acceptable only if sufficient data are provided to justify the emission reductions estimated.

e. *Program alterations.* Alternations to program design during the course of an I/M program will be evaluated on a case-by-case basis. Such alternations might include: change from an idle test, after several years of use, to a loaded test; change from annual inspection, after several years of use, to a semiannual inspection.

f. *Cutpoint variations.* For a given stringency factor (which is based on both hydrocarbons and carbon monoxide), individual cutpoints for hydrocarbons and carbon monoxide can be varied in a theoretically infinite number of ways. The reductions given in this Appendix assume that there is a particular relationship between hydrocarbon and carbon monoxide cutpoints. This relationship, though considerably more complex than mentioned here, can be generally stated as, for Technology I vehicles, two carbon monoxide failures for each hydrocarbon failure, and for Technology II vehicles, three carbon monoxide failures for each hydrocarbon failure. It is possible that an area's particular pollution problem may call for I/M cutpoints that result in substantial deviations from the HC/CO relationships implicit in this Appendix. At the State's or local area's request, EPA will review the program's cutpoint structure, and make adjustments to emissions reduction credit as necessary.

g. *High altitudes, California.* All emission reductions estimated in this section are also applicable to high altitude areas and for vehicles equipped for use in California.

h. *Oxides of nitrogen.* It has not been shown that maintenance directed at reducing HC and CO emissions has a significant impact on oxide of nitrogen (NOx) emissions. All available data show very minor increases or decreases in NOx levels. It has already been cited (Section 6(a)) that a loaded test is capable of detecting high NOx emitters. Maintenance procedures and an ensuing control strategy to reduce NOx emissions, based on I/M, are therefore conceivable. To the extent that tampering is directed toward NOx emission controls, a good anti-tampering program can reduce NOx emissions.

ATTACHMENT 1

DESCRIPTION OF THE SIMULATION MODEL

Introduction. Empirical data from ongoing inspection/maintenance (I/M) programs has shown that mandatory inspection and maintenance will result in significant air quality benefits. Increased future benefits are to be expected as such programs become stabilized, i.e., the vehicle population has been subject to I/M requirements during its full lifetime. Currently available data, however, is somewhat limited in its ability to estimate these future benefits quantitatively. For this reason, a mathematical model of the I/M process has been developed, in which available empirical data is utilized to make the model as realistic as possible. This approach was used to derive the estimates of benefit presented in Appendix N. Two groups of vehicles were considered, and these groups of vehicles are designated as Technology I and Technology II. Technology I vehicles include all light-duty vehicles manufactured prior to the 1975 model year that were designed to meet pre-1975 exhaust emission standards. Technology II vehicles include all post-1974 light-duty vehicles that were de-

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signed to meet the more stringent 1975 and later emission standards. Samples of vehicles of the two technology levels were input to the model, and were taken as representative of Technology I and Technology II vehicles on a nationwide basis. Please note: all computations in Attachments 1 and 2 are based upon the metric system.

I. *Description of the simulation model of the inspection/maintenance process.* The I/M process as currently conceived in the model consists of the following events:

1. Emission deterioration from existing levels.
2. Inspection lane testing of HC and CO levels using the idle test to detect high FTP emitters (NOx emissions are insignificant at idle, and therefore are not considered in the model).
3. Maintenance or repair (resulting in lower emission levels), if a vehicle fails the inspection.

Each vehicle undergoes this sequence of events throughout its useful life, which is assumed to be nine years, or approximately 160,000 kilometers.

The model compares average FTP emissions in the case where an I/M program is operational, with emissions in the case where no I/M program exists. Benefit is calculated as the percent reduction in FTP emissions from the average level in the no I/M case. FTP emission levels art used to measure benefit since the FTP driving cycle is assumed to be representative of vehicle operation in urban areas. Two types of benefit can be computed: (1) the average benefit over a vehicle's life, and (2) the benefit in a particular year of a vehicle's life. Both types of benefit are dependent upon the vehicle's level of emission control technology and the number of times the vehicle has been subjected to a mandatory inspection program. The average benefit for a population of vehicles in a given calendar year is computed from the individual technology level vehicle benefits given in Appendix N, which are of the second type. The calculation methodology is discussed in a later section of this Appendix.

Issues affecting estimated I/M benefit. Benefit due to I/M depends upon the assumptions used to implement the simulation of the I/M process; that is, the assumptions surrounding the three events identified above. Because the currently available data are limited, assumptions were made regarding some of the issues that logically affect benefit. The model reflects these assumptions, which were based on engineering judgment. The issues and assumptions are discussed below.

Issue 1. Emission levels of vehicles at first inspection.

Concept. Benefit in the first and subsequent inspection years is expected to depend on the emission levels of vehicles at their first inspection. There are two ways in which differences in the first year emission levels could produce significant differences in benefit. First, it is possible that for vehicles of a given age there will be differences in the distribution of emission levels at first inspection from one technology level to another; for example, it might be the case that for one technology level vehicles have either very low or very high emissions at first inspection, whereas for another technology level vehicles have emissions which are clumped closely together around some average value. This situation could possibly result in more benefit for the first technology level case, even if the same percentage of vehicles of each technology level were to fail an inspection, since failures in the first technology level case could result in bigger drops in emissions percentagewise. Second, within a technology level, different emission levels at the time of I/M implementation will naturally exist for different model year vehicles, and it is possible that these absolute numerical differences will result in benefit (or percentage) differences as well.

Assumptions. The first year Appendix N benefits, and indirectly the benefits for each subsequent inspection year, were determined by analyzing the emissions performance of one-year-old cars with and without I/M. Separate benefits were calculated for the Technology I and Technology II cases. Technology I first year benefits were based on emissions data on 180 1973–74 models tested in the FY '73 Emission Factor Program. Technology II first year benefits were based on emissions data on 587 1975 models tested in the FY '74 Emission Factor Program. These vehicles were taken to be representative of the nationwide mix of low altitude non-California one-year-old Technology I and Technology II vehicles, respectively, in terms of mileage and maintenance characteristics. As Appendix N benefit numbers indicate, I/M benefits differ by technology level, at least for CO.

With regard to different first year emission levels that all model year vehicles, regardless of age, obtain the same first year benefits. This assumption is based upon the premise that, for public acceptance reasons, the first year pass/fail cutpoints would differ with age or model year so that all vehicles would experience similar failure rates. Limited data indicate that under this premise, benefits (on a percentage-wise basis) are similar.

Issue 2. Emission deterioration.

Concept. Emission deterioration is the process whereby vehicle emission rates increase over time from the levels at which the vehicles were intended to emit when new. Emission deterioration includes changes in emissions due to normal wear of engine/emission control components as well as changes in emissions due to tampering or poor maintenance.

Assumptions. The deterioration rates used in the model are expressed as a percentage of low mileage average FTP values per year. These percentage rates are assumed to be equal for all vehicles of a given technology level, and are constant over time. Specifically, the rates were taken to be 18 percent per year for HC and 15 percent per year for CO for Technology I vehicles; 21 percent per year for HC and 14 percent per year for CO for technology II vehicles. These rates are based on data from EPA's FY '71 through FY '74 Emission Factor Programs and represent vehicle deterioration under typical owner maintenance practices. For a given pollutant and vehicle, the model considers the FTP rate of deterioration per year (grams/kilometer/year) to be constant over time. Thus, deterioration is modeled as a linear phenomenon. The grams/kilometer/year value is calculated as the overall deterioration rate, (in percent) multiplied by the individual vehicle's first-year emission level. Thus, each vehicle is considered to be an inherently low or high emitter with respect to each pollutant; vehicles-which have low emissions when new will continue to have relatively low emissions as they accumulate mileage. Emissions of vehicles in the no I/M case are assumed to deteriorate throughout their useful life until they reach the average levels of pre-controlled cars at 161,000 kilometers (100,000 miles).

Significant percentages of catalytic converter failure may occur with increasing vehicle age and if such a situation does occur, the emission rates will increase sharply in later years: that is, a constant deterioration rate assumption will not be valid. However, the surveillance data currently available to EPA do not cover mileage ranges extensive enough to estimate the frequency and effect of such failures.

The FTP deterioration rate (grams/kilometer/year) is assumed not to be affected by the existence of an I/M program. However, if an I/M program is operational, the deterioration process is not continuous because deterioration is interrupted by annual idle test emissions inspections. If a vehicle fails the idle test, its emissions are assumed to be reduced via maintenance or repair to meet the pre-determined idle test standards. The FTP emissions are assumed to be reduced correspondingly, as determined by regression relationships. Following an I/M repair, the deterioration process continues under the assumption that a vehicle's yearly rate of deterioration (gm/km) is unaffected by the repair that occurred. The implication is that the inherent emissions characteristics of a vehicle cannot be improved via repair. If a vehicle passes the idle test, its emissions are left unchanged for the calculation of the average emission levels (gm/km) following the round of I/M. The deterioration process then continues until the next annual inspection occurs.

The idle test deterioration rate per year (percent CO or ppm HC) is also assumed to be constant over time for each vehicle. Idle test deterioration rates are determined from FTP deterioration rates using the following rationale: The effectiveness of I/M in reducing in-use vehicle emissions as measured over the FTP requires that the short test used in the inspection lane be an accurate predictor of FTP passage or failure. One way to ensure this is to define the idle deterioration rate in terms of the FTP deterioration rate. Currently in the model the assumption is made that FTP emissions can be quantitatively predicted from idle test emissions, and vice versa. The idle deterioration rate for a given vehicle is determined from the FTP deterioration rate and a regression relationship. Based on data over a limited mileage range, the relationships are assumed to be independent of milage and maintenance state.

Issue 3. Short test pass/fail cutpoints.

Concept. The purpose of an inspection/maintenance program is to reduce the emissions of in-use vehicles as measured over the FTP. A short emissions test procedure is intended to provide a practical method (i.e., quick and inexpensive) for identifying high FTP emitting vehicles. The benefit associated with an I/M program is dependent on the methodology used to determine the short test pass/fail cutpoint for each pollutant from year to year. The method of determining initial short test cutpoints has varied in practice from assigning cutpoints that are make/model specific to assigning one set of cutpoints for all light duty vehicles with similar emission control technology. The possibility of changing short test cutpoints to reflect vehicle age is also an important consideration.

Assumptions. The HC and CO cutpoints on which the Appendix N benefits are based are technology level specific. Thus, all vehicles of a given emission control technology (for example, catalyst-equipped cars) are assumed to have the same cutpoints. Cutpoints for the first year of the simulated I/M program were set by first specifying a stringency factor and then analyzing appropriate EPA emission factor data on one-year-old vehicles which were assumed to be representative of the nationwide mix of one-year-old vehicles. The analysis resulted in the determination of idle test pass/fail cutpoints for HC and O which corresponded to the specified stringency factor (ranging from 10 percent to 50 percent). For example, if a 30 percent stringency factor was specified, then HC and CO idle test cutpoints were determined so that approximately 30 percent of all vehicles would fail the idle test at the first inspection assuming that owners did not change their maintenance habits from those typically in effect prior to the implementation of I/M.

The relative stringency factors for HC and CO were determined by assuming that a car emitting at twice the HC FTP standard is equally likely to be failed as a car which is emitting at twice the CO FTP standard. This assumption is only one of an infinite number of ways that relative HC and CO stringency factors could be weighted to achieve the specified overall stringency factor. For example, since more AQCRs exceed ambient oxidant emission standards than exceed ambient CO standards, a car at twice the HC FTP emission standard could be considered equally likely to fail as a car which is at four times the CO FTP standard. The result of the weighting criterion which was applied is that at stringency levels below 30 percent, the large majority of vehicle failures can be attributed to high CO emission levels; even though significant percentages of HC failure are detected at stringency levels of 40 percent and above, HC failure is never as high as CO failure, percentagewise.

One of the model's critical assumptions with regard to cutpoint specification is that the first year cutpoints continue to be used year after year to determine which vehicles will pass or fail the idle test. One implication of the assumption of maintaining constant cutpoints over time is that vehicles can continue to be repaired to meet the same standards year after year, regardless of vehicle age or mileage. In support of this assumption, data from the 1972 and 1973 EPA In-use Compliance Program (IUCP) programs indicate that vehicles can continue to be repaired to FTP levels well below short test levels which represent 50 percent stringency levels.

If service industry repair capability is assumed to be minimal (as in the base case Appendix N credits, where failed vehicles are repaired just to meet the idle test cutpoints), another implication is that the percentage of failed vehicles increases over time to about twice the initial stringency factor if, as the model assumes, significant voluntary owner maintenance does not occur. Data from I/M programs in New Jersey and Chicago indicate that the failure rates of a given model year of vehicles do not increase significantly as vehicles age, even though the same cutpoint is applied. Thus, either considerable voluntary maintenance is occurring or mechanics are repairing vehicles to levels significantly better than the minimum required repair levels.

Issue 4. Service industry repair capability.

Concept. Air quality benefit derived from an I/M program is dependent on the ability of the service industry to perform the repair work necessary to lower emissions. Depending on the level of service industry training, idle emissions could be reduced just to the cutpoints, or well below the cutpoints, potentially resulting in different benefits to air quality.

Assumptions. The base case benefits given in Table 1 of Appendix N assume that the service industry is capable of repairing all failed vehicles exactly to the idle test cutpoints. Then the equivalent FTP levels are computed so that the average urban benefits can be calculated. The model assumes that a vehicle which is failed incorrectly on the idle test does not have its FTP emissions either raised or lowered by the repair process. The model also assumes that a vehicle which fails for one pollutant only will have the other pollutant emissions lowered to the FTP equivalent idle standard in cases where errors of emission occurred.

Additional benefit is predicted if mechanic training is in effect. The model assumes that mechanic training would result in the reduction of emissions of failed vehicles to the FTP standards. As in the base case, the model assumes that if a vehicle fails for one pollutant only, the other pollutant will also be reduced to the FTP standard if an error of emission occurred. The first year credits indicate a dependency on stringency factor. For catalyst vehicles, the tendency is for mechanic training to have the largest effect on programs with stringency factors of 20 and 30 percent. This is reasonable because the effect of mechanic training is jointly dependent on the percent of cars failed and the degree of improvement in the FTP levels of repaired vehicles resulting from the mechanic training program: If only 10 percent of all cars are failed initially, then only 10 percent of all cars are repaired so that even an apparently significant increased reduction due to mechanic training will be somewhat dampened by the fact that a good percentage of the remaining cars are undoubtedly high FTP emitters which simply were not caught. If, on the other hand, 50 percent are failed and the FTP standards in gm/km are approximately equal to the FTP levels corresponding to the more stringent idle test cutpoints, additional benefit due to mechanic training would be insignificant. For precatalyst CO, the tendency described above, although less apparent, still seems to be present. However, precatalyst HC exhibits a tendency for mechanic training to have an increasing effect with increasing stringency factor. The tendency is explained by the fact that for the data which were input to the computer program, the HC FTP standards in gm/km was significantly lower than the FTP level corresponding to the idle test HC cutpoint, even at stringencies of 40 to 50 percent. As a result, an increased percentage of failed vehicles continued to produce increased benefit due to mechanic training.

The model assumes that owner tampering following the sequence of events: failure of the idle test, vehicle repair, and subsequent passage of the idle test, does not occur. Since motorists frequently attribute driveability problems to properly-functioning emission control devices, this assumption may be somewhat unrealistic unless mechanics become more knowledgeable about the tradeoffs between performance and emission rates. However, a good estimate of the frequency and effect of owner tampering (either with or without I/M) is not available at the present time. Moreover, the benefit credits given in Appendix N require the existence of an effective anti-tampering program.

Issue 5. Frequency of inspection.

Concept. Since emission deterioration is modeled to occur continuously over time, the frequency of inspection determines the extent of vehicle deterioration between inspections. The more frequent the inspection, the less the vehicles deteriorate and thus the greater the I/M benefit.

Assumptions. For the base case benefits given in Appendix N, inspections are modeled to take place annually. Additional benefits result from semi-annual inspections. The difference in benefits from the annual to the semi-annual case is presented in section 3(c) of Appendix N.

Issue 6. Short test procedure used in the inspection lane.

Concept. Since the intent of an I/M program is to reduce the emissions of in-use vehicles as measured over the FTP, one would ideally be able to design a short emissions test procedure whose results could be used to accurately predict FTP emission levels. From a practical standpoint, the short test procedure must be quick, inexpensive, and applicable to vehicles in a warmed-up condition.

Assumptions. Benefits presented in Appendix N are based on the assumption that the idle test is used in the inspection lane. Limited analysis using the simulation model indicates that benefits using the idle test and a loaded test are comparable since the two tests are equally able to identify high FTP emitters.

ATTACHMENT 2

METHODOLOGY FOR APPLYING APPENDIX N BENEFIT NUMBERS

Tables 1 and 2 of Appendix N provide the I/M benefit numbers necessary to calculate the estimated calendar year percent reduction in HC and CO emissions from emission levels expected in the absence of I/M. To determine the percent reduction in HC and CO emissions for a given calender year, the Appendix N numbers must be applied to the scenario in question. The scenario is specified in determining the following for the calendar year *i* of interest:

1. The calendar year, *y*, in which an I/M program was implemented.
2. The number or percentage of vehicles of each model year ($i-12$ through i) contributing to the total vehicle population (vehicles of model years earlier than $i-12$ should be considered as model year $i-12$).
3. Average vehicle kilometers traveled by each model year group of vehicles.
4. HC and CO emission factors (grams/kilometer) for each model year group of vehicles, assuming I/M has never been in effect.

The calculation of emission reduction in kilograms for a given pollutant (HC or CO) in calender year *i* is performed as follows:

$$D_i = \sum_{t=i-12}^{i} b_{it} c_{it} m_{it} n_{it},$$

where

b_{it} = percent reduction in emissions for vehicles of model year *t* in calendar year *i*.[2]

c_{it} = emission factor (grams/kilometer) for vehicles of model year *t* in calendar year *i*, assuming I/M has never been in effect.

m_{it} = average kilometers traveled by vehicles of model year *t* in calendar year *i*.

n_{it} = number of vehicles of model year *t* in calendar year *i*.

[2] The benefit numbers in Tables 1 through 4 of Appendix N (which represent both the base case of I/M and the case where mechanic training and/or a semi-annual program is in effect), can be used to determine b_{it} by identifying the technology level represented by vehicles of model year *t* and the number of inspections which vehicles of model year *t* have undergone by the beginning of calendar year *i*. The number of inspections can be calculated formally as the minimum of $(i-y)$ and $(i-t)$ for an annual I/M program, where *i* is the calendar year of interest, *y* is the year in which I/M was implemented, and *t* is the model year. It is assumed that the maximum number of annual inspections for vehicles of all model years will be eight. For purposes of calculating benefit, model year vehicles which have undergone more than eight inspections should be treated as if only eight have been undergone.

The calculation of benefits in percent, B_i, in calendar year *i* requires one further step:

$$B_i = 100\, D_i \Big/ \left(\sum_{t=i-12}^{i} c_{it} m_{it} n_{it} \right).$$

where the definitions of *m*, *n*, and *c* are as above.

If only the percent reduction is of interest, rather than the kilograms, the following alternative calculation of B_i can be used:

$$B_i = 100 \frac{\sum_{t=i-12}^{i} b_{it} e_{it} m_{it} p_{it}}{\sum_{t=i-12}^{i} c_{it} m_{it} p_{it}}.$$

where *b*, *e*, and *m*, are defined as above, and *p* is the fraction of vehicles on the road in calendar year *i* which are of model year *t*.

The calculation of the scenario's reduced emission factor (grams/kilometer) in calen-

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dar year t as a result of I/M, is performed as follows:

$$(BF)_t=\frac{(100-B_t)}{100}\cdot\left(\sum_{i=t-12}^{t} e_{it}m_{it}n_{it}\right)\Big/\left(\sum_{i=t-12}^{t} m_{it}n_{it}\right),$$

where B_i, e_{it}, m_{it}, and n_{it} are as defined above. (Replacement of n_{it} with p_{it} will yield the same numerical results).

Appendix N can also be used to compute the average percentage benefit of I/M for a given vehicle over its useful life, which is assumed to be nine years or approximately 150,000 kilometers and represents eight annual I/M inspections. If the vehicle is of model year t and I/M began in calendar year y, this percent reduction in emissions for a specific pollutant is computed as follows:

$$U_t=100\cdot\left(\sum_{k=t}^{t+8} b_{k,t}e_{k,t}m_{k,t}\right)\Big/\left(\sum_{k=t}^{t+8} e_{k,t}m_{k,t}\right),$$

where

k=calendar years covering the useful life of a vehicle of model year t: $k=t, t+1, \cdots, t+8$.

$b_{k,t}$=percent reduction in emissions for vehicles of model year t in calendar year k.[3]

$e_{k,t}$=emission factor (grams/kilometer) for vehicles of model year t in calendar year k, assuming I/M has never been in effect.

$m_{k,t}$=average kilometers traveled by vehicles of model year t in calendar year k.

Nationwide estimates of the number of vehicles of each model year in the calendar year of interest, and average kilometers traveled by each model year vehicle for the calendar year of interest can be obtained by referring Table 1 which provides nationwide estimates of number of vehicles by vehicle age, and average kilometers traveled by vehicle age. Nationwide estimates of emission factors by calendar year are available in AP-42. Tables 2 and 3 provide, for illustrative purposes only, sample emission factors for calendar years 1977-1980 in format to be utilized in the upcoming revision of AP-42, Supplement 5.

Examples of the application of the methodology for calculating benefit.

Specification of scenario for problem examples 1 and 2. The nationwide mix of vehicles by age and average VKTs, as given in AP-42, applies. An I/M program with a 40 percent stringency factor was implemented in 1973, and vehicles one-year-old or older were tested by the end of calendar year 1973.

Problem 1. Determine the present reduction in emissions for HC and CO in CY 1977, assuming that the I/M inspections are annual, and that no mechanic training program is in effect.

Solution. The percent reduction, B_{77}, can be calculated from the formula:

$$B_{77}=\frac{\sum_{t=77-12}^{77} b_{77,t}e_{77,t}m_{77,t}p_{77,t}}{\sum_{t=77-12}^{77} e_{77,t}m_{77,t}p_{77,t}}\times 100,$$

where

$b_{77,t}$=percent reduction in emissions for vehicles of model year t in calendar year 1977 (obtained from Appendix N),

$e_{77,t}$=emission factor (gm/km) for vehicles of model year t in calendar year 1977, assuming I/M has never been in effect (obtained from AP-42),

$m_{77,t}$=average kilometers traveled by vehicles of model year t in calendar year 1977 (obtained from AP-42)

$p_{77,t}$=fraction of total vehicles on the the road in calendar year 1977 which are of model year t (obtained from AP-42).

Note that the denominator of B_{77} is the usual AP-42 type calculation of emission factors.

The following tables detail the calculation of both the numerator and denominator of B_{77} for HC and CO:

t	$b_{77,t}$ (percent)	$e_{77,t}$	$m_{77,t}$	$p_{77,t}$	Numerator product	Denominator product
1977	0	0.9	25.6	0.081	0	1.86
1976	16	1.1	24.2	.110	.47	2.93
1975	23	1.2	22.5	.107	.66	2.89
1974	24	2.9	21.1	.106	1.56	6.48
1973	30	3.4	19.6	.102	2.04	6.80
HC 1972	30	2.7	18.2	.096	1.94	6.46
1971	30	4.1	16.6	.088	1.80	5.99
1970	30	4.5	15.1	.077	1.57	5.23
1969	30	4.9	13.7	.064	1.29	4.30
1968	30	5.3	12.2	.049	.95	3.17
Pre-1968	30	6.1	10.8	.120	2.37	7.96
					14.66	54.07

HC: $B_{77}=(14.7/54.1)\times1.00=.27$.

t	$b_{77,t}$ (percent)	$e_{77,t}$	$m_{77,t}$	$p_{77,t}$	Numerator product	Denominator product
1977	0	14.7	25.6	0.081	0	30.5
1976	33	16.6	24.2	.110	14.8	44.2
1975	41	18.6	22.5	.107	15.4	44.8
1974	34	35.3	21.1	.106	26.8	78.9
1973	38	39.5	19.6	.102	30.0	79.0
CO 1972	38	43.7	18.2	.096	27.0	76.3
1971	38	47.9	16.6	.088	25.6	70.0
1970	38	52.1	15.1	.077	23.0	60.6
1969	38	56.3	13.7	.064	15.5	49.4
1968	38	60.5	12.2	.049	13.7	36.2
Pre-1968	33	77.3	10.8	.120	33.2	100.4
					239.1	670.3

CO: $B_{77}=(239.1/670.3)\times1.00=.36$.

Problem 2. Determine the percent reduction in emissions, B_{77}, for HC and CO in CY 1977, assuming that the inspections are annual and that an adequate mechanic training program is in effect.

Solution. The method used for Problem 1 applies. Only the $b_{77,t}$ numbers will differ to reflect the presence of an adequate program of mechanic training. The following tables detail the calculation of both numerator and denominator of B_{77} for HC and CO:

t	$b_{77,t}$ (percent)	$e_{77,t}$	$m_{77,t}$	$p_{77,t}$	Numerator product	Denominator product
1977	0	0.9	25.6	0.081	0	1.87
1976	17	1.1	24.2	.110	.50	2.93
1975	25	1.2	22.5	.107	.72	2.89
1974	35	2.9	21.1	.106	2.27	6.49
1973	41	3.4	19.6	.102	2.79	6.80
HC 1972	41	2.7	18.2	.096	2.65	6.46
1971	41	4.1	16.6	.088	2.46	5.99
1970	41	4.5	15.1	.077	2.13	5.23
1969	41	4.9	12.7	.064	1.78	4.30
1968	41	5.3	12.2	.049	1.30	3.17
Pre-1968	41	6.1	10.8	.120	3.24	7.91
					19.54	54.04

HC: $B_{77}=(19.5/54.0)\times1.00=.37$.

t	$b_{77,t}$ (percent)	$e_{77,t}$	$m_{77,t}$	$p_{77,t}$	Numerator product	Denominator product
1977	0	14.7	25.6	0.081	0	30.5
1976	40	16.6	24.2	.110	17.7	44.2
1975	51	18.6	22.5	.107	22.8	44.8
1974	47	35.3	21.1	.106	37.1	73.9
1973	51	39.5	19.6	.102	40.3	79
CO 1972	51	43.7	18.2	.096	38.9	76.3
1971	51	47.9	16.6	.088	35.7	70
1970	51	52.1	15.1	.077	30.9	60.6
1969	51	56.3	13.7	.064	25.2	49.4
1968	51	60.5	12.2	.049	18.5	36.2
Pre-1968	51	77.3	10.8	.120	51.2	100.4
					318.2	670.2

CO: $B_{77}=(318.2/670.2)\times1.00=.48$.

Specification of scenario for problem example 3. The nationwide mix of vehicles by age and average VKT, as given in AP-42, applies. An I/M program with a 30% stringency factor was implemented in calendar year 1980, and vehicles one year old or older were tested by the end of calendar year 1980. The program is annual and no mechanic training program is in effect. Since the emissions characteristics of 1978 and later model year cars are unknown, it will be assumed that the initial year emissions from these vehicles will be the same as that determined for 1975 model year vehicles by the Agency's Emission Factor Program: namely, .87 gm./km. HC and 14.7 gm./km. CO. Also, it will be assumed that 1978 and later model year vehicles deteriorate at the same rate as 1975-77 models; namely, .17 gm/km./yr. HC and 1.93 gm./km./yr. CO.

Problem 3. Determine the percent reduction in emissions, B_{90}, for HC and CO in calendar year 1990, and the resulting reduced emission factors for HC and CO for calendar year 1990.

Solution. To calculate B_{90}, the method used in the solutions to Problems 1 and 2 applies. The following tables detail the numerical calculation of both numerator and denominator of B_{90} for HC and CO.

t	$b_{90,t}$ (per cent)	$e_{90,t}$	$m_{90,t}$	$p_{90,t}$	Numerator product	Denominator product
1990	0	0.9	25.6	0.081	0	1.87
1989	9	1.1	24.2	.110	.28	2.93
1988	16	1.2	22.5	.107	.46	2.89
1987	23	1.4	21.1	.106	.72	3.13
1986	29	1.6	19.6	.102	.93	3.20
1985	34	1.7	18.2	.096	1.01	2.97
HC 1984	39	1.9	16.6	.088	1.08	2.78
1983	42	2.0	15.1	.077	.98	2.32
1982	45	2.2	13.7	.064	.88	1.93
1981	45	2.4	12.2	.049	.65	1.44
1980	45	2.4	10.8	.033	.38	.86
Pre-1980	45	2.4	10.8	.087	1.01	2.28
					8.34	28.58

HC: $B_{90}=(8.3/28.6)\times1.00=.29$.

t	$b_{90,t}$ (percent)	$e_{90,t}$	$m_{90,t}$	$p_{90,t}$	Numerator product	Denominator product
1990	0	14.7	25.6	0.081	0	30.5
1989	28	16.6	24.2	.110	12.4	44.2
1988	36	18.6	22.5	.107	16.1	44.8
1987	43	20.6	21.1	.106	19.8	46.1
1986	47	22.5	19.6	.102	21.1	45.0
1985	51	24.5	18.2	.096	21.8	42.8
CO 1984	55	26.4	16.6	.088	21.2	38.6
1983	58	28.4	15.1	.077	19.2	33.0
1982	63	30.3	13.7	.064	16.7	28.6
1981	63	32.3	12.2	.049	12.2	19.3
1980	63	32.3	10.8	.033	7.3	11.5
Pre-1980	63	32.3	10.8	.087	19.1	30.3
					186.9	412.7

CO: $B_{90}=(186.9/412.7)\times1.00=.45$.

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[3] The benefit numbers in Tables 1 through 4 of Appendix N (which represent both the base case of I/M and the case where mechanic training and/or a semi-annual program is in effect), can be used to determine $b_{k,t}$, by identifying the technology level represented by vehicles of model year t and the number of inspections which vehicles of model year t have undergone by the beginning of calendar year k. The number of inspections (for calendar years after calendar year y) can be calculated formally as the minimum of $(k-y)$ and $(k-t)$ for an annual I/M program, where y is the year in which I/M was implemented, t is the model year, and k is the calendar year. Note that $b_{k,t}=0$ for k less than or equal to y.

To calculate the reduced emission factors for HC and CO, the following formula can be used:

$$(EF)_{80}=\frac{100-B_{80}}{100}\times\frac{\sum_{i=80-12}^{80} e_{80,i}\,m_{80,i}\,p_{80,i}}{\sum_{i=80-12}^{80} m_{80,i}\,p_{80,i}}$$

The following tables detail the calculation of the numerator and denominator:

i	$e_{80,i}$	$m_{80,i}$	$p_{80,i}$	Numerator product	Denominator product
1970	0.9	25.6	0.081	2.07	1.87
1969	1.1	24.2	.110	2.93	2.66
1968	1.2	22.5	.107	2.89	2.41
1967	1.4	21.1	.106	3.13	2.24
1966	1.6	19.6	.102	3.20	2.00
1965	1.7	18.2	.096	2.97	1.73
HC 1964	1.9	16.6	.088	2.78	1.46
1963	2.0	15.1	.077	2.32	1.16
1962	2.2	13.7	.064	1.98	.88
1961	2.4	12.2	.049	1.43	.60
1960	2.4	10.8	.033	.86	.36
Pre-1960	2.4	10.8	.087	2.25	.94
				25.78	18.22

HC: $(EF)_{80}=.79\times\frac{25.8}{18.2}=1.12$ g/km.

i	$e_{80,i}$	$m_{80,i}$	$p_{80,i}$	Numerator product	Denominator product
1970	14.7	25.6	0.081	30.5	2.07
1969	16.6	24.2	.110	44.2	2.66
1968	18.6	22.5	.107	44.8	2.41
1967	20.6	21.1	.106	46.1	2.24
1966	22.5	19.6	.102	45.0	2.00
1965	24.5	18.2	.096	42.8	1.45
CO 1964	28.4	16.6	.088	41.5	1.40
1963	25.4	15.1	.077	33.0	1.16
1962	30.3	13.7	.064	23.6	.88
1961	32.3	12.2	.049	19.3	.60
1960	32.3	10.8	.033	11.5	.36
Pre-1960	32.3	10.8	.087	30.3	.94
				412.7	18.24

CO: $(EF)_{80}=.55\times\frac{412.7}{18.2}=12.5$ g/km.

TABLE 1.—*Estimated fraction of vehicles in use nationwide and average annual kilometers driven nationwide, by vehicle age*

Vehicle age, in years	Fraction of vehicles	Average annual kilometers driven, in thousands
1	0.081	25.6
2	.110	24.2
3	.107	22.5
4	.106	21.1
5	.102	19.6
6	.096	18.2
7	.088	16.6
8	.077	15.1
9	.064	13.7
10	.049	12.2
11	.033	10.8
12+	.087	10.8

Source: AP–42.

TABLE 2.—*Emission factors for light-duty, gasoline-powered vehicles (automobiles) (low altitude, non-California)*

Model year	Carbon monoxide, grams/kilometer; calendar year—			
	1977	1978	1979	1980
Pre-1968	77.5	77.5	77.5	77.5
1968	60.5	60.5	60.5	60.5
1969	56.3	60.5	60.5	60.5
1970	52.1	56.5	60.5	60.5
1971	47.9	52.1	56.5	56.5
1972	42.7	47.9	52.1	56.5
1973	39.5	42.7	47.9	52.1
1974	33.3	39.5	42.7	47.9
1975	18.6	20.6	22.5	24.5
1976	16.6	18.6	20.6	22.5
1977	14.7	16.6	18.6	20.6

TABLE 3.—*Emission factors for light-duty, gasoline-powered vehicles (automobiles) (low altitude, non-California)*

Model year	Hydrocarbons, grams per kilometer; calendar year			
	1977	1978	1979	1980
Pre-1968	6.1	6.1	6.1	6.1
1968	5.3	5.3	5.3	5.3
1969	4.9	5.3	5.3	5.3
1970	4.5	4.9	5.3	5.3
1971	4.1	4.5	4.9	5.3
1972	3.7	4.1	4.5	4.9
1973	3.4	3.7	4.1	4.5
1974	2.9	3.4	3.7	4.1
1975	1.2	1.4	1.6	1.8
1976	1.1	1.2	1.4	1.6
1977	.9	1.1	1.2	1.4

[FR Doc.77–12296 Filed 4–29–77;8:45 am]

FEDERAL COMMUNICATIONS COMMISSION

[47 CFR Part 73]

[Docket No. 21205; RM–2781]

TV BROADCAST STATION IN LIHUE, HAWAII

Proposed Change in Table of Assignments

AGENCY: Federal Communications Commission.

ACTION: Proposed rule making.

SUMMARY: Notice of Proposed Rule Making is issued in response to petition for educational television channel in Lihue (Kauai) Hawaii.

DATES: Comments must be received on or before May 31, 1977, and reply comments must be received on or before June 21, 1977.

ADDRESSES: Send comments to: Federal Communications Commission, Washington, D.C. 20554.

FOR FURTHER INFORMATION CONTACT:

Stanley Schmulewitz, Policy and Rules Division, Broadcast Bureau (202–632–9660).

SUPPLEMENTARY INFORMATION:

Adopted: April 15, 1977.

Released: April 22, 1977.

In the matter of amendment of § 73.606(b), table of assignments, television broadcast stations (Lihue (Kauai), Hawaii).

1. The Commission, by the Chief, Broadcast Bureau, has before it for consideration a petition for rule making filed by the Hawaii Public Broadcasting Authority ("Authority"). The petition seeks amendment of Section 73.606(b) of the Commission's Rules, the Television Table of Assignments, by assigning Channel 67 to Lihue (Kauai), Hawaii and reserving it for noncommercial educational use.

2. We are told that the Authority is an agency created by an Act of the state legislature of Hawaii for the purpose of making educational television available to the citizens of Hawaii on a coordinated state-wide basis. In pursuance of its statutory mandate, the Authority operates noncommercial educational Station KHET, Channel 11, Honolulu, and noncommercial educational Station KMEB, Channel 10, Wailuku, which operates as a satellite of Station KHET. In addition, the Authority is operating or plans to operate a series of translator facilities which it believes to be the most efficient, cost-effective method of spreading public television to the less populated areas of the Hawaiian Islands.

3. The objective here is to be able to serve the area of Lihue, Kauai Island, with a one kilowatt translator on Channel 67.[1] This channel is requested although Channels 21 and 27 are already allocated to the community and reserved for educational use. The reason given by the Authority for the request is that virtually all receiving antennas on the Island of Kauai are designed for Channels 55 and above. This appears to be borne out by existing translator licenses on Channels 70, 74, 76 and 78 in Lihue.

4. Lihue (pop. 3,124) is located on the Island of Kauai (pop. 27,761), the westernmost of the principal Hawaiian Islands and is approximately 160 kilometers (100 miles) northwest of Honolulu. The proposed assignment meets all spacing requirements and would allow improved educational television service on the Island of Kauai. Other channels

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[1] Pursuant to paragraph 4 of the *Report and Order* in Docket No. 18861, 36 FR 19588, 23 R.R. 2d 1504 (1971), high-powered UHF translators such as this may be operated only on unoccupied channels which are listed in the Television Table of Assignments. See also §§ 74.702(g) and 74.735(e) of the rules.

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Appendix C

SHORT-TEST EMISSIONS STANDARDS AS RELATED TO FEDERAL CONSTANT VOLUME SAMPLING TESTING

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Appendix C

SHORT-TEST EMISSIONS STANDARDS AS RELATED TO FEDERAL CONSTANT VOLUME SAMPLING TESTING

The correlation attributes between short test programs and FTP tests for noted gaseous emissions for model-year 1975 are presented in Figures C-1, C-2, and C-3. In setting pass/fail limits in a mandatory inspection program using modal testing, it is required to set concentration standards that relate in a logical manner to the Federal Constant Volume Sampling (CVS) test procedure.

U.S. Environmental Protection Agency (EPA) report "Evaluation of Restorative Maintenance on 1975 and 1976 Light-duty Vehicles in Detroit, Michigan" presented emission test results for individual vehicles for test types noted in Table C-1. This data is plotted in the graphs as noted above for idle mode. The data, along with its statistical analysis, indicates a low level of correlation. Superimposed on the graph is a Federal Test Procedure to short test procedure regression relationship established by the EPA (Ref. 7).

Table C-2 presents correlation coefficient for short-test emission measurement procedures on a California 1972 Idle Inspection Fleet Test Program.

Idle Test Correlation and Commission Errors

Until there is a sufficient data base that describes the operational characteristics of emission control systems, it is not possible to determine with certainty the adequacy of various emission test procedures in identifying malfunctions of those systems. The relative importance of identifying various types of malfunctions cannot be determined until operating experience with substantial numbers of new and future emission control systems has been gained.

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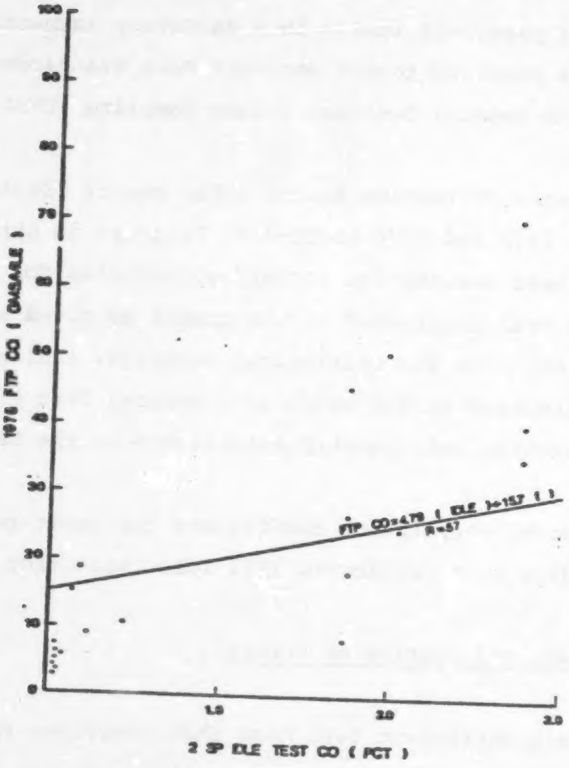


Fig. C-1
CO Emissions
Idle Mode

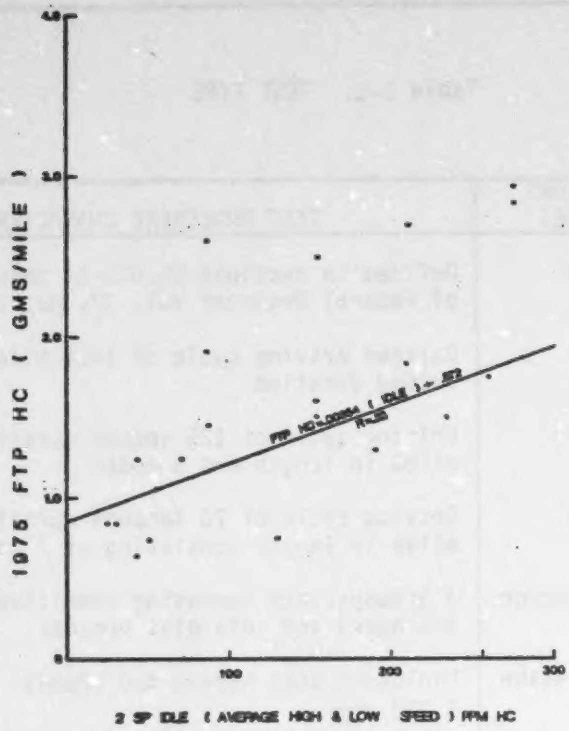


Fig. C-2
HC Emissions
Idle Mode

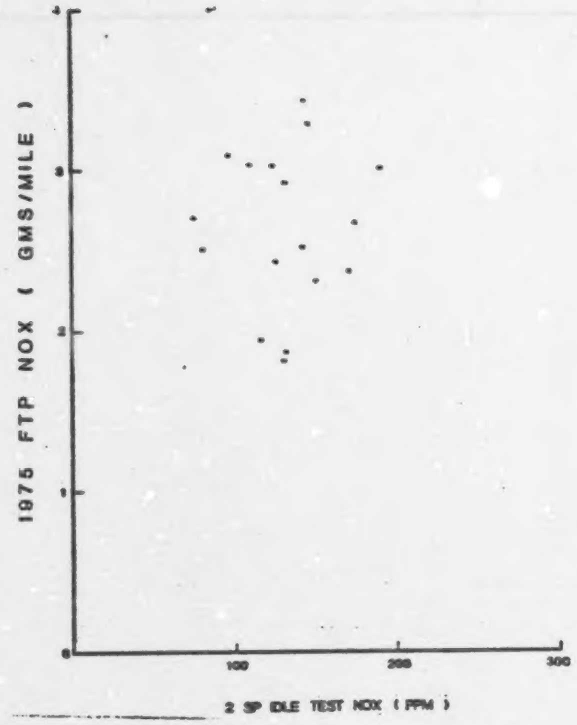


Fig. C-3
NO_x Emissions
Idle Mode

Table C-2.

CORRELATION COEFFICIENTS FOR SHORT TEST EMISSION MEASUREMENT PROCEDURES

1972 FTP REGRESSION BEFORE SERVICE

CALIFORNIA IDLE INSPECTION FLEET DATA

Test Procedure	Emission Measurement	Correlation Coefficient			Standard Error of Estimate Grams Per Mile		
		HC	CO	NOx	HC	CO	NOx
Federal Short Cycle	Mass	0.94	0.81	0.74	2.5	32	1.1
Seven Mode Cycle	Mass	0.91	0.70	0.70	3.1	38	1.1
Key Mode (multiple regression)	Mass	0.96	0.81	0.66	2.2	32	1.2
Steady State Modes (mult. regression)	Mass	0.96	0.82	0.71	2.2	32	1.2
Idle Mode	Mass	0.80	0.62	0.15	4.4	42	1.6
Seven Mode Cycle	Volumetric	0.57	0.77	0.43	6.0	34	1.4
Key Mode (multiple regression)	Volumetric	0.79	0.68	0.61	4.5	40	1.3
Steady State Modes (mult. regression)	Volumetric	0.81	0.68	0.63	4.4	40	1.3
Idle Mode	Volumetric	0.35	0.50	0.02	6.8	46	1.6

However, some general conclusions can be drawn based upon the general characteristics of various test procedures.

The Federal Certification Test Procedures (FTP) is considered the standard for measuring vehicle emission because it is representative operation in urban areas. The idle-mode emission test, as compared with the FTP, provides for testing a limited number of operating conditions.

The potential shortcomings of the idle-mode test for emission testing is its inability to diagnose malfunctions of exhaust gas recirculation (EGR) systems which are currently used by most automobile manufacturers to ensure compliance with the 1973 Federal NO_x emission standards. When the EGR valve is functioning properly, there is no recirculation of the exhaust gas during idle operation; therefore, the system provides no reduction of idle NO_x emissions. A malfunction of the EGR system causing an increase in NO_x emission during loaded operating modes would not result in a concurrent increase in idle-mode emissions. The malfunction would, therefore, remain undetected by an idle test measurement.

A loaded-emission test, on the other hand, includes a wider range of operating conditions and would be more generally useful in testing future vehicles. However, all current short emission tests are hampered by their inability to measure cold-start emissions, which is so important for vehicles equipped with catalytic and thermal reactor emission control system.

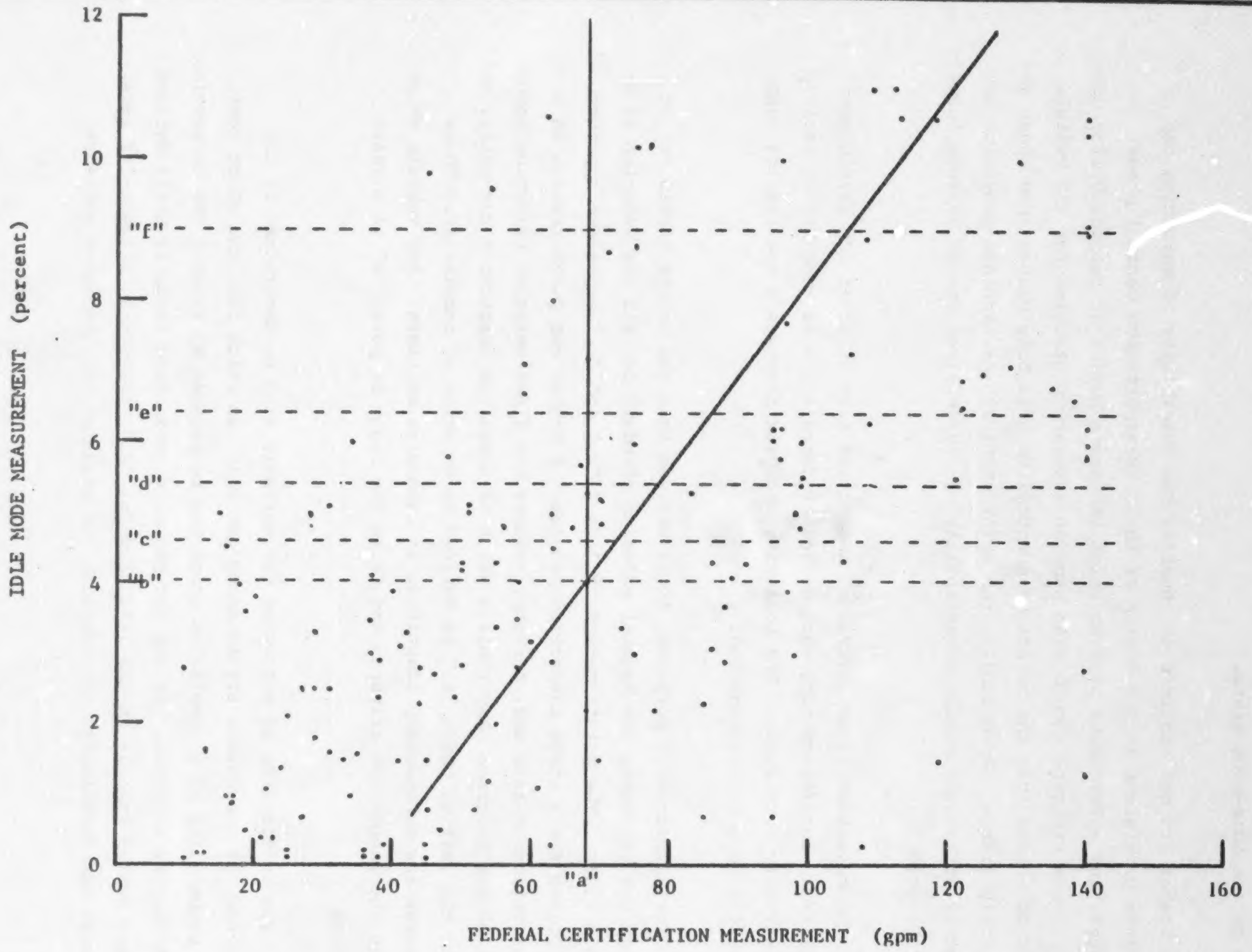
The evaluation of alternative inspection procedures must also consider their relationship to enforcing the warranty provisions set forth in Section 207 of the Clean Air Act. That section authorizes the EPA to establish regulations requiring automobile manufacturers to warrant the emission control performance of every new motor vehicle for the vehicle's useful life. To implement this provision, Section 207 requires that there be available short-test procedures which achieve adequate correlation with the FTP. While the definition of adequate correlation is yet to be established, it is clear that those short tests which achieve the highest degree of correlation will be most likely to satisfy the requirements for adequate correlation. The correlation analyses have consistently shown that for current vehicles, the dynamic (loaded) tests, as a general category, achieve significantly higher correlation with the FTP than do the idle-mode tests.

States are not required to consider the feasibility of enforcing the warranty provisions in the design of their transportation control plans. However, any enforcement program which imposes a burden of responsibility upon the private citizen, should also provide adequate protection for the vehicle owner to ensure that the burden of noncompliance is only placed upon those who are truly liable. Accordingly, the enforcement of the warranty provision may directly affect the public acceptability of any enforced in-use vehicle inspection program.

The selection of an individual inspection test requires the development of criteria for determining what degree of correlation is adequate to satisfy the warranty provisions. The following analysis provides a qualitative means of making such a determination.

For illustrative purposes, it is assumed that the points marked "a" in Figure C-4 represent the Federal emission standard for all the vehicles in a sample fleet. The points marked "b," "c," "d," and "e," represent hypothetical cut points for a state inspection program. A higher cut point results in a lower rejection rate and, thereby, reduces the fleet emission reduction potential of the program. Any vehicle which is above the inspection cut point, and is to the left of point "a," is defined as an error of commission. These vehicles are erroneously identified as excessive emitters. Any vehicle which fails the inspection criteria and is to the right of point "a" is a valid failure.

The feasibility of enforcing the warranty will be determined by the frequency of commission errors among the vehicles which fail the short test. The probability of a commission error can be reduced by raising the inspection test failure criteria. At any cut point, a commission error is still defined as any failed vehicle to the left of point "a." Therefore, a trade-off exists between the feasibility of enforcing the warranty and the fleet emission



Correlation Coefficient = .375

Figure C-4.
CARBON MONOXIDE EMISSION IDLE MODE TEST CYCLE VERSUS FTP

SCi SYSTEMS CONTROL, INC.
ENVIRONMENTAL ENGINEERING DIVISION

reduction achieved by the inspection strategy. The degree of correlation between the two test procedures is a measure of the extent to which the short-test failure criteria must be raised to reduce the errors of commission to an acceptable level.

Table C-3 presents the results of applying this type of analysis for the idle-mode test procedure. The rejection rate, the frequency of commission errors, and the fleet emission reductions are shown for selected short test cut points.

Table C-3. ERRORS OF COMMISSION FOR IDLE-MODE SHORT-TEST PROCEDURES

TEST TYPE	REJECTION RATE %	FREQUENCY OF COMMISSION ERRORS % OF FAILED VEHICLES	FLEET EMISSION REDUCTION AFTER MAINTENANCE (CO Emissions) %
Idle Mode Test	50	43	17
(Corr. Coef. = 0.375)	40	40	15
	30	30	10
	20	30	12
	10	27	8
	5	14	4

The results of this analysis are not intended to provide sufficient information to determine the failure criteria which should be used in a state program. The test fleet used to demonstrate this analysis was composed of the total model-year mix of the 1972 California vehicle population. The individual failure criteria would have to be determined for each model-year such that the commission errors were reduced to an acceptable level. However, Table C-3 does demonstrate the impact of the trade-off between commission errors and the fleet emission reduction potential for idle-mode test.

Appendix D

GENERAL DEFINITIONS

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Appendix D

GENERAL DEFINITIONS

The following definitions and abbreviations are those commonly used in inspection and emissions testing procedures.

accuracy: The degree by which an instrument is able to determine the true concentration of a pollutant in the exhaust gas sampled.

air contaminants: Any fumes, smoke, particulate matter, vapor gas, or any combination, but excluding water vapor or stream condensate.

air-fuel ratio: The expression of the proportional mixture of air and gasoline created by the carburetor. Usually expressed as a numerical relationship such as 14:1, 13:1, etc.

ambient air: The surrounding or outside air.

calibration gases: A blend of HC and CO gases using nitrogen as a carrier gas.

carbon monoxide: A nonirritating, colorless, odorless gas at standard conditions which has the molecular form of CO.

catalytic emission control system: Device to reduce automobile emissions by converting CO and HC emissions to harmless carbon dioxide and water.

certificate of compliance: A document which is issued upon completion of the inspection which records the results of the inspection and serves as proof of said inspection for vehicle owner.

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certified mechanic: An individual licensed to install, repair and adjust motor vehicle engine emissions-related components and pollution control devices in order that the motor vehicle meet applicable emissions standards.

certified station: A private facility licensed to install, repair and adjust motor vehicle engine emissions-related components and pollution control devices in order that the motor vehicle meet applicable emissions standards.

chassis dynamometer: A machine equipped with two parallel rollers which support the rear wheels of a motor vehicle. When positioned on the dynamometer the vehicle may be "driven" to simulate the loadings the engine would experience when the vehicle is operated on the road. A power absorption unit is connected to the rollers to simulate the loading from the various sources of fluid and mechanical friction present during road operation. Weights can also be coupled to the rollers to simulate the inertial effects of vehicle mass during acceleration and deceleration.

crankcase emissions: The products of combustion emitted into the ambient air from portions of the engine crankcase ventilation or lubrication system.

degradation: The decreased effect of I/M on emission reduction due to normal wear of engine system.

deterioration: A synonym for degradation indicating an increase in emission levels due to wear.

drift: The amount of meter reading change over a period of time. Zero drift refers to change of zero reading. Span drift refers to a change in reading of a calibration point on the upper half of the scale. The calibration point is established by reading a calibration gas of known concentration.

emission inspection program: An inspection and maintenance program in which each vehicle is subjected at specified intervals to a test of its emissions under specified conditions. The emission levels are compared with a standard established for the vehicle class. If the emissions are higher than the standard, the vehicle is failed and must be adjusted or repaired to bring its emissions into compliance with the standards.

engine family: The basic classification unit of a manufacturer's product line used for the purpose of test fleet selection.

engine-system combination: An engine family-exhaust emission control system-fuel evaporative emission control system combination.

exhaust gas analyzer: An instrument for sensing the amount of air contaminants in the exhaust emissions of a motor vehicle.

exhaust emissions: The products of combustion emitted into the ambient air from any opening downstream of the exhaust ports of a motor vehicle engine.

fleet owner authorized stations: A permit issued to a qualified fleet owner to perform vehicle emissions inspection limited to his fleet only.

fleet operator: The owner of a fleet of a designated number of vehicles.

fuel system: Combination of fuel tank, feeder lines, fuel pump, and evaporative control system.

gross vehicle weight: The manufacturer's gross weight rating for the individual vehicle.

hang-up: HC which clings to the surface of the sampling and analyzer system in contract with the gas sample stream which causes an erroneous indication of HC in the measured value.

heavy-duty vehicle: Any motor vehicle designed for highway use which has a gross vehicle weight of more than 8,500 pounds. A heavy-duty gasoline powered vehicle is designated as HDG. A heavy-duty diesel-powered vehicle is designated as HDD.

hydrocarbons:	A compound whose molecular composition consists of atoms of hydrogen and carbon only.
idle test:	An emission inspection program which measures the exhaust emission from a motor vehicle operating at idle. (No motion of the rear wheels.) A vehicle with an automatic transmission may be in drive gear with brakes applied or in neutral gear.
independent contractor:	Any person, business firm, partnership or corporation with whom the state may enter into an agreement providing for the construction, equipment, maintenance, personnel, management and operation of official inspection stations.
inspection and maintenance program:	A program to reduce emissions from in-use vehicles through identifying vehicles that need emissions control-related maintenance and requiring that maintenance be performed.
inspection station:	A centralized facility for inspecting motor vehicles and pollution control devices for compliance with applicable regulations.
inspector:	An individual who inspects motor vehicles and pollution control devices for compliance with applicable regulations.
instrument:	The system which samples and determines the concentration of the pollutant gas.
key-mode test:	A loaded mode test in which exhaust emissions are measured at high- and low-cruise speeds and at idle. The cruise speeds and dynamometer power absorption settings vary with the weight class of the vehicle. The dynamometer loading in the high-cruise range is higher than normal load in order to more effectively expose malfunctions leading to high emissions.
light-duty vehicle (LDV):	A motor vehicle designed for highway use of less than 8,500 pounds gross vehicle weight. Further distinctions are sometimes made between light-duty automobiles and light-duty trucks such as

pickup trucks. Light-duty gasoline-powered truck, category 1 (LDT_1) is a motor vehicle on a truck chassis, 0-6,000 pounds gross vehicle weight (GVW). A light-duty gasoline-powered truck, category 2 (LDT_2) is a motor vehicle on a truck chassis, 6,000-8,500 pounds GVW.

loaded mode test: An emission inspection program which measures the exhaust emissions from a motor vehicle operating under simulated road load on a chassis dynamometer.

model year of vehicle: The production period of new vehicle or new vehicle engines designated by the calendar year in which such period ends.

motorcycle: A motor vehicle having a seat or saddle for use of the rider and designed to travel on not more than three wheels in contact with the ground, but excluding a tractor.

motor vehicle: Any self-propelled vehicle which is designed primarily for travel on public right-of-ways and which is used to transport persons and property.

oxides of nitrogen: Sum of nitric oxide and nitrogen dioxide contained in a gas sample as if the nitric oxide were in the form of nitrogen dioxide.

positive crankcase ventilation: A system designed to return blowby gases from the crankcase of the engine to the intake manifold so that the gases are burned in the engine. Blowby gas is unburned fuel/air mixture which leaks past the piston rings into the crankcase during the compression and ignition cycles of the engine. Without positive crankcase ventilation these gases, which are rich in hydrocarbons, escape to the atmosphere.

prescribed inspection procedure: Approved procedure for identifying vehicles that need emissions control-related maintenance.

quality: The composite product characteristics of engineering and manufacturing that determine the degree to which the product in use meets customer expectations.

quality assurance: A system for integrating the quality functions of various organizational groups to assure production and service at the most economical levels satisfying quality requirements of test facility or contractor.

registered owner: An individual, firm, corporation or association whose name appears in the files of the motor vehicle registration division of the Department of Motor Vehicles as the person to whom the vehicle is registered.

repeatability: The instrument's capability to provide the same value for successive measures of the same sample.

response time: The period of time required by an instrument to provide meaningful results after a step change in gas concentration level initiated at the tail pipe sample probe.

smoke: Small gasborne and airborne particles, exclusive of water vapor, arising from a process of combustion in sufficient number to be observable.

stringency factor: The percentage of total vehicles tested in an inspection/maintenance program in a given time period that fail inspection and are required to have maintenance performed.

system or device: Equipment designed for installation on a motor vehicle for the purpose of reducing pollutants emitted from the vehicle, or a engine modification causing pollutant reduction.

tampering: The illegal alteration, modification, or disconnection of emission control device or adjustments or manufacturer tuning specifications on motor vehicles for the purpose of controlling vehicle emissions.

vehicle dealer: An individual, firm, corporation or association who is licensed to sell motor vehicles.

vehicle emissions standard: A specific emission limit allowed for a class of vehicles. The standard is normally expressed in terms of maximum allowable concentrations of pollutants (e.g., parts per million). However, a standard could also be expressed in terms of mass emissions per unit of time or distance traveled (e.g., grams per mile).

Appendix E

COST AND FEE CALCULATIONS

Appendix E

COST AND FEE CALCULATIONS

This appendix provides the detailed method used in calculating annual costs and fees.

E.1 TIME VALUE OF MONEY

Analysis of economic activities requires comparison of sums of money (cash flows) at various points in time. This means we need methods which will enable us to take into account the time value of money (interest).

The values of sums of money at different points in time depend upon the interest rate and the time spans. A sum of money today is not equivalent to the same sum ten years later unless interest were assumed at the unrealistic rate of zero.

The present value (P) of a future sum (S) that yields n years from now is calculated as follows:

$$P = S \times \left[\frac{1}{1+i}\right]^n$$

where i is the interest rate.

Another useful concept is the annualized worth of a present sum. For example, if a borrower applies loan of P dollars from a bank, the interest is i.

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What is the yearly uniform payment that he has to pay back in n years? This type of question can be answered with the following formula:

$$R = P \left[\frac{i(1+i)^n}{(1+i)^n - 1} \right]$$

where:

R is the uniform payment per year
P is the present sum
n is the number of years
i is the interest.

E.2 CONSUMER FEE CALCULATIONS

The consumer fee, F_c is calculated by dividing total uniform annualized cost by the average number of vehicles inspected per year. This fee is designed to defray all of the costs, except certain state overhead expenses incurred on the implementation of an I/M program.

E.3 INFLATION EFFECT

The above mentioned fee is in constant dollars. To consider the inflation effect, an adjustment factor must be applied.

Let the projected annual inflation rate be i. The consumer fee in constant dollars is F_c. Let the uniform fee in actual dollar be F_a. The relationship between F_a and F_c can be derived as follows:

$$F_a = \frac{(F_c + F_c(1+i) + F_c(1+i)^2 + --- + F_c(1+i)^{n-1})\ (1+i)^{Y-1}}{n}$$

$$= F_c \times \frac{(1+i)^n - 1}{n \times i} (1+i)^{Y-1}$$

where τ is the number of years to the starting year of I/M program, and n is the program period. The term

$$\frac{(1+i)^{n}-1}{n \times i}(1+i)^{\tau-1}$$

is the adjustment factor for inflation.

For example, if an I/M program starts in 1982 and continues for 10 years, the adjustment factor to 1978 constant dollars with 7 percent inflation rate is calculated as follows:

$$(1+0.07)^{4} \times ((1+0.007)^{10} -1/10 \times 0.07 = 1.81$$

Appendix F

TAMPERING AS A VEHICLE EMISSIONS PROBLEM

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Appendix F

TAMPERING AS A VEHICLE EMISSIONS PROBLEM

The possible areas associated with tampering are:

- Carburetor adjustments to improve driveability at the expense of emissions
- Installation of replacement of after market parts which are not to manufacturer's specifications
- Converter catalyst
- Timing and advance
- Exhaust gas recirculation (EGR) interruption

Of the items listed the EGR tampering is the major problem and will be reviewed as to its effect on NO_x emissions.

Exhaust Gas Recirculation (EGR) is used on vehicles to reduce oxides of nitrogen (NO_x). In the heat of combustion (3,500-4,000°F) nitrogen combines with oxygen forming oxides of nitrogen. Combustion temperatures must be lowered to reduce formation NO_x. The EGR system consists of a valve, solenoid control, back pressure transducer, temperature control, hoses, clamps, and wiring. A typical vehicle emissions control system with EGR is presented in Figure F-1.

The heart of the EGR system is an EGR valve. The valve passes small amounts of exhaust gas into the intake manifold below the carburetor. Very

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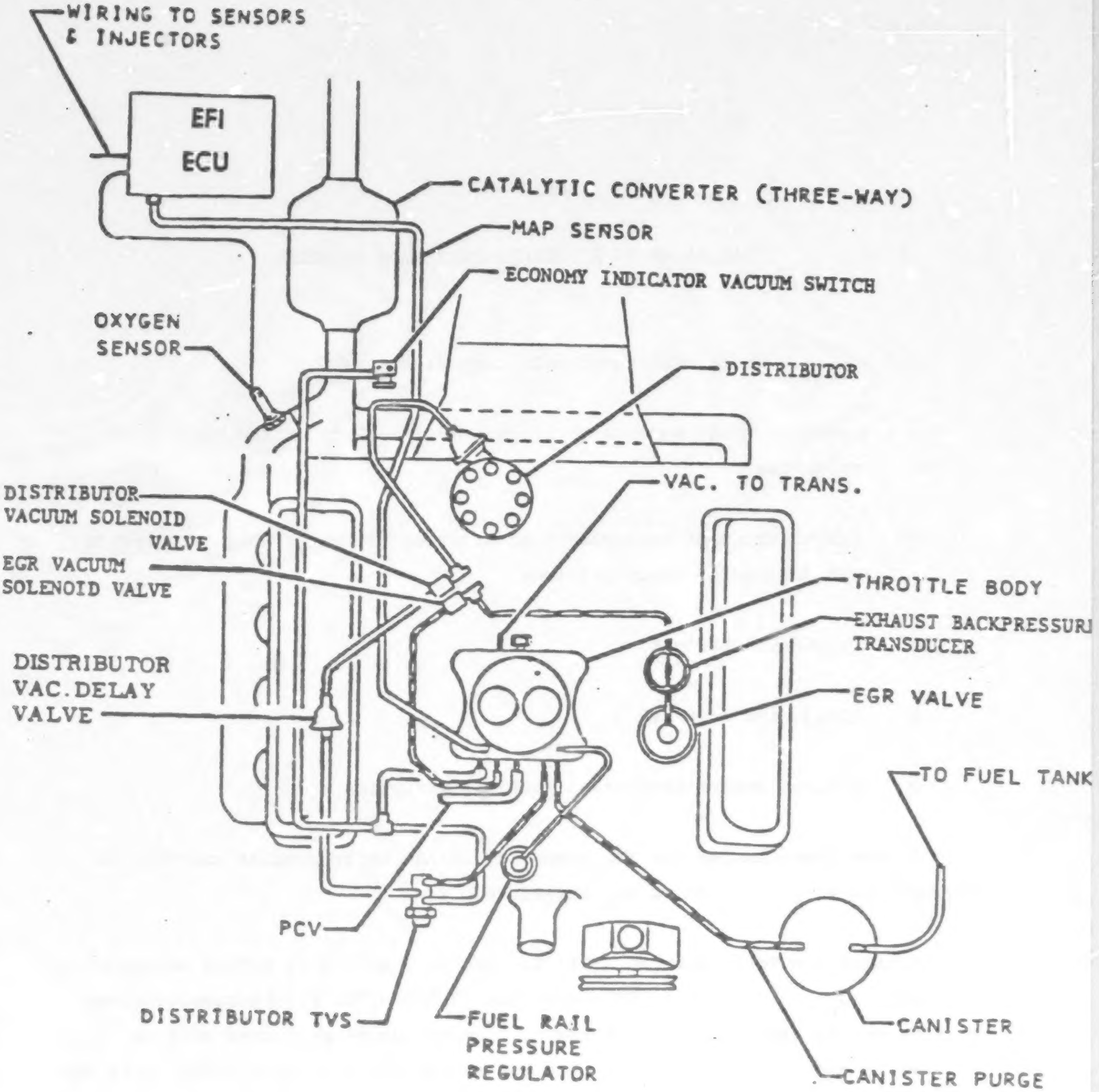
WIRING TO SENSORS & INJECTORS
EFI ECU
CATALYTIC CONVERTER (THREE-WAY)
MAP SENSOR
ECONOMY INDICATOR VACUUM SWITCH
OXYGEN SENSOR
DISTRIBUTOR
VAC. TO TRANS.
DISTRIBUTOR VACUUM SOLENOID VALVE
EGR VACUUM SOLENOID VALVE
THROTTLE BODY
EXHAUST BACKPRESSUR
TRANSDUCER
DISTRIBUTOR VAC.DELAY VALVE
EGR VALVE
TO FUEL TANK
PCV
DISTRIBUTOR TVS
FUEL RAIL PRESSURE REGULATOR
CANISTER
CANISTER PURGE

Figure F-1. TYPICAL EMISSION CONTROL SYSTEMS SHOWING EGR SYSTEM

▭ PORTED VACUUM

▭ MANIFOLD VACU

little NO_x is formed at idle or light engine loads but formation increases rapidly during acceleration. As the throttle opens, the EGR valve opens, recirculating exhaust gases to reduce NO_x. EGR valves are carefully matched to each type of engine. Use of the wrong valve may cause driveability and performance problems or increased emissions. The valve air flow varies with temperature, vacuum signal, and atmospheric pressure.

Description of Tampering

- System hoses missing
- Steel ball in vacuum hose
- Top of EGR valve is dimpled reducing stroke thereby the vacuum status
- Drilled holes for air access
- Coolant thermostat switch alteration
- Vacuum amplifier modification
- Vacuum line notched or cut

The existent of tampering of EGR valve by dealers in a California study was very extensive. The dealers inspected were in the normal complaint and inspection routine of the field investigation section of the ARB, El Monte Vehicle Branch during 1977. In the 400 in-use vehicle surveillance program by California ARB, tampering occurs as a result of driveability and was in the 18 to 20 percent range.

Vehicle Emissions Effects

The EGR malfunction with a 20 percent failure rate results in approximately 49 percent increase in emissions (reference Table F-1).

Table F-1. TYPICAL EMISSIONS BEFORE AND AFTER TAMPERING REPAIRS

TEST TYPE	HC	CO	NO_x	CO_2	REMARK
Std I	3.2	39.0	2.0		
EMISSIONS BEFORE REPAIR					
CVS-75 (gm/mi)	2.311	19.20	6.78	438.6	18.7 mpg
CVS-72 Recalculated	2.66	26.44	6.43	460.12	
HWY Cycle (gm/mi)	1.129	5.14	8.93	393.8	21.9 mpg
Loaded Mode					
	69.0	0.17	3106.0	13.65	H
	95.0	0.12	2371.0	13.37	L
wo/A	121.0	1.55	136.0	13.37	I
EMISSIONS AFTER REPAIR					
CVS-75 (gm/mi)	2.554	21.49	1.64	571.7	14.5
(CVS-75 12	3.36	28.03	1.62	588.84	
HWY Cycle (gm/mi)	1.073	8.25	1.19	431.0	19.8 mpg
Loaded Mode	43.0	0.25	832.0	14.68	H
	86.0	0.15	657.0	14.33	L
wo/A	86.0	0.70	141.0	14.00	I

$$\text{\% Increase Because of Tampering} = \frac{\text{Emissions with 20\% tampering} - \text{Emissions per certification}}{\text{Emissions per Vehicle certification}}$$

$$\text{For 20\% Tampering} = \frac{(.80) \times 2 + (.20) \times 6.78 - (1.00) \times 2}{1.00 \times 2}$$

$$= \frac{1.6 + 1.356 - 2}{2} = \frac{.956}{2} = 49\%$$

Appendix G

COMPILATION OF AIR POLLUTANT EMISSION FACTORS

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Appendix H

HEAVY-DUTY, DIESEL-POWERED VEHICLES

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Appendix G[a]

COMPILATION OF AIR POLLUTANT EMISSION FACTORS

3.1.3 Light-Duty, Diesel-Powered Vehicles

3.1.3.1 General – In comparison with the conventional, "uncontrolled," gasoline-powered, spark-ignited, automotive engine, the uncontrolled diesel automotive engine is a low pollution powerplant. In its uncontrolled form, the diesel engine emits (in grams per mile) considerably less carbon monoxide and hydrocarbons and somewhat less nitrogen oxides than a comparable uncontrolled gasoline engine. A relatively small number of light-duty diesels are in use in the United States.

3.1.3.2 Emissions – Carbon monoxide, hydrocarbons, and nitrogen oxides emission factors for the light-duty, diesel-powered vehicle are shown in Table 3.1.3-1. These factors are based on tests of several Mercedes 220D automobiles using a slightly modified version of the Federal light-duty vehicle test procedure.[1,2] Available automotive diesel test data are limited to these results. No data are available on emissions versus average speed. Emissions from light-duty diesel vehicles during a calendar year (n) and for a pollutant (p) can be approximately calculated using:

$$e_{np} = \sum_{i=n-12}^{n} c_{ipn} \, m_{in} \qquad (3.1.2\text{-}1)$$

where: e_{np} = Composite emission factor in grams per vehicle mile for calendar year (n) and pollutant (p)

c_{ipn} = The 1975 Federal test procedure emission rate for pollutant (p) in grams/mile for the i^{th} model year at calendar year (n) (Table 3.1.3-1)

m_{in} = The fraction of total light-duty diesel vehicle miles driven by the i^{th} model year diesel light-duty vehicles

Details of this calculation technique are discussed in section 3.1.2.

The emission factors in Table 3.1.3-1 for particulates and sulfur oxides were developed using an average sulfur content fuel in the case of sulfur oxides and the Dow Measuring Procedure on the 1975 Federal test cycle for particulate.[1,6]

Table 3.1.3-1. EMISSION FACTORS FOR LIGHT-DUTY, DIESEL-POWERED VEHICLES
EMISSION FACTOR RATING: B

Pollutant	Emission factors, Pre-1973 model years	
	g/mi	g/km
Carbon monoxide[a]	1.7	1.1
Exhaust hydrocarbons	0.46	0.29
Nitrogen oxides[a,b] (NO_x as NO_2)	1.6	0.99
Particulate[b]	0.73	0.45
Sulfur oxides[c]	0.54	0.34

[a] Estimates are arithmetic mean of tests of vehicles, References 3 through 5 and 7.

[b] Reference 4.

[c] Calculated using the fuel consumption rate reported in Reference 7 and assuming the use of a diesel fuel containing 0.20 percent sulfur.

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[a] Reprinted form "Compilation of Air Pollutant Emission Factors," U.S. Environmental Protection Agency, February 1976.

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Appendix H[a]

HEAVY-DUTY, DIESEL-POWERED VEHICLES

3.1.5 Heavy-Duty, Diesel-Powered Vehicles

3.1.5.1 General[1,2] – On the highway, heavy-duty diesel engines are primarily used in trucks and buses. Diesel engines in any application demonstrate operating principles that are significantly different from those of the gasoline engine.

3.1.5.2 Emissions – Diesel trucks and buses emit pollutants from the same sources as gasoline-powered vehicles: exhaust, crankcase blow-by, and fuel evaporation. Blow-by is practically eliminated in the diesel, however, because only air is in the cylinder during the compression stroke. The low volatility of diesel fuel along with the use of closed injection systems essentially eliminates evaporation losses in diesel systems.

Exhaust emissions from diesel engines have the same general characteristics of auto exhausts. Concentrations of some of the pollutants, however, may vary considerably. Emissions of sulfur dioxide are a direct function of the fuel composition. Thus, because of the higher average sulfur content of diesel fuel (0.20 percent S) as compared with gasoline (0.035 percent S), sulfur dioxide emissions are relatively higher from diesel exhausts.[3,4]

Because diesel engines allow more complete combustion and use less volatile fuels than spark-ignited engines, their hydrocarbon and carbon monoxide emissions are relatively low. Because hydrocarbons in diesel exhaust represent largely unburned diesel fuel, their emissions are related to the volume of fuel sprayed into the combustion chamber. Both the high temperature and the large excesses of oxygen involved in diesel combustion are conducive to high nitrogen oxide emission, however.[6]

Particulates from diesel exhaust are in two major forms – black smoke and white smoke. White smoke is emitted when the fuel droplets are kept cool in an environment abundant in oxygen (cold starts). Black smoke is emitted when the fuel droplets are subjected to high temperatures in an environment lacking in oxygen (road conditions).

Emissions from heavy-duty diesel vehicles during a calendar year (n) and for a pollutant (p) can be approximately calculated using:

$$e_{nps} = \sum_{i=n-12}^{n} c_{ipn} v_{ips} \qquad (3.1.5\text{-}1)$$

where: e_{nps} = Composite emission factor in g/mi (g/km) for calendar year (n), pollutant (p), and average speed (s)

c_{ipn} = The emission rate in g/mi (g/km) for the i^{th} model year vehicles in calendar year (n) over a transient urban driving schedule with an average speed of approximately 18 mi/hr (29 km/hr)

v_{ips} = The speed correction factor for the i^{th} model year heavy-duty diesel vehicles for pollutant (p) and average speed (s)

Values for c_{ipn} are given in Table 3.1.5-1. These emission factors are based on tests of vehicles on-the-road over the San Antonio Road Route (SARR). The SARR, located in San Antonio, Texas, is 7.24 miles long and includes freeway, arterial, and local/collector highway segments.[7] A constant volume sampler is carried on board

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[a] Reprinted from "Compilation of Air Pollutant Emission Factors," U.S. Environmental Protection Agency, February 1976.

each test vehicle for collection of a proportional part of the vehicle's exhaust. This sample is later analyzed to yield mass emission rates. Because the SARR is an actual road route, the average speed varies depending on traffic conditions at the time of the test. The average speed, however, tends to be around 18 mi/hr (29 km/hr), with about 20 percent of the time spent at idle. The test procedure emission factor is composed entirely of warmed-up vehicle operation. Based on a preliminary analysis of vehicle operation data, heavy-duty vehicles operate primarily (about 95 percent) in a warmed-up condition.

Table 3.1.5-1. EMISSION FACTORS FOR HEAVY-DUTY, DIESEL-POWERED VEHICLES (ALL PRE-1973 MODEL YEARS) FOR CALENDAR YEAR 1972
EMISSION FACTOR RATING: B

Pollutant	Truck emissions[a]		City bus emissions[b]	
	g/mi	g/km	g/mi	g/km
Particulate[c]	1.3	0.81	1.3	0.81
Sulfur oxides[c,d] (SO_x as SO_2)	2.8	1.7	2.8	1.7
Carbon monoxide	28.7	17.8	21.3	13.2
Hydrocarbons	4.6	2.9	4.0	2.5
Nitrogen oxides (NO_x as NO_2)	20.9	13.0	21.5	13.4
Aldehydes[c] (as HCHO)	0.3	0.2	0.3	0.2
Organic acids[c]	0.3	0.2	0.3	0.2

[a] Truck emissions are based on over-the-road sampling of diesel trucks by Reference 7. Sampling took place on the San Antonio (Texas) Road Route (SARR), which is 7.24 miles (11.7 kilometers) long and includes freeway, arterial, and local/collector highway segments. Vehicles average about 18 mi/hr (29 km/hr) over this road route.

[b] Bus emission factors are also based on the SARR. 13-Mode emission data from Reference 6 were converted to SARR values using cycle-to-cycle conversion factors from Reference 8.

[c] Reference 6. Tire wear particulate not included in above particulate emission factors. See tire wear particulate, heavy-duty gasoline section.

[d] Data based on assumed fuel sulfur content of 0.20 percent. A fuel economy of 4.6 mi/gal (2.0 km/liter) was used from Reference 9.

The speed correction factor, v_{ips}, can be computed using data in Table 3.1.5-2. Table 3.1.5-2 gives heavy-duty diesel HC, CO, and NO_x emission factors in grams per minute for the idle mode, an urban transient mode with average speed of 18 mi/hr (29 km/hr), and an over-the-road mode with an average speed of approximately 60 mi/hr (97 km/hr). For average speeds less than 18 mi/hr (29 km/hr), the correction factor is:

$$v_{ips} = \frac{\text{Urban} + \left(\frac{18}{S} - 1\right) \text{Idle}}{\text{Urban}} \qquad (3.1.5\text{-}2)$$

where: s is the average speed of interest (in mi/hr), and the urban and idle values (in g/min) are obtained from Table 3.1.5-2. For average speeds above 18 mi/hr (29 km/hr), the correction factor is:

$$v_{ips} = \frac{\frac{18}{42S}\left[(60\text{-}S)\ \text{Urban} + (S\text{-}18)\ \text{Over the Road}\right]}{\text{Urban}} \qquad (3.1.5\text{-}3)$$

Where: S is the average speed (in mi/hr) of interest. Urban and over-the-road values (in g/min) are obtained from Table 3.1.5-2. Emission factors for heavy-duty diesel vehicles assume all operation to be under warmed-up vehicle conditions. Temperature correction factors, therefore, are not included because ambient temperature has minimal effects on warmed-up operation.

Table 3.1.5-2. EMISSION FACTORS FOR HEAVY-DUTY DIESEL VEHICLES UNDER DIFFERENT OPERATING CONDITIONS
EMISSION FACTOR RATING: B

Pollutant	Emission factors[a] g/min		
	Idle	Urban [18 mi/hr (29 km/hr)]	Over-the-road [60 mi/hr (97 km/hr)]
Carbon monoxide	0.64	8.61	5.40
Hydrocarbons	0.32	1.38	2.25
Nitrogen oxides (NO_x as NO_2)	1.03	6.27	28.3

[a] Reference 7. Computed from data contained in the reference.

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